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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE BUD-ROT OF PALMS IN INDIA

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PREFACE.

The following account of the bud-rot of palms in South India is written because the continuance of the work to which it relates has passed from my hands to those of the recently appointed Mycologist to the Madras Department of Agriculture, Mr. W. McRae.

I have pleasure in acknowledging much assistance from the notes of field observations and experiments supplied by Messrs. S. Sundararaman and D. Balakrishna Murti of the Madras Department of Agriculture and S. N. Mitra and R. Sen of the Mycological Laboratory, Pusa.

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MAP of the area affected by Palm disease in **GODAVARI** and **KISTNA** Districts.

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I.—INTRODUCTION.

A group of palm diseases, the chief symptom of which is a rot in the soft tissues of the interior of the crown, has attracted much attention in tropical countries in recent years. The "Kew Bulletin" for 1893[1] quotes a description of a coconut disease observed in Jamaica in 1891[2], and states that it appears to be allied to an obscure disease known as coconut "fever" in Honduras and to a disease observed in British Guiana in 1875-6. A similar disease destroyed many coconut groves in Cuba in 1886, and a report on it was published at Havana in 1888. After the occupation of that island by the United States, coconut palms were found to be dying in large numbers from a mysterious disease. In 1901, Mr. A. Busck of the Division of Entomology of the United States Department of Agriculture reported that it was probably caused by the fungus Pestalozzia palmarum, a common palm-leaf parasite, but that bacteria seemed to play some part.[3] Professor F. S. Earle saw the disease in Jamaica in 1902 and believed it to be of bacterial origin.[4] The same view was taken in 1905 by Dr. Erwin F. Smith of the United States Department as regards the Cuba disease.[5] It was next observed in Trinidad by Mr. Hart in 1905, and attention again

1 W. F. H. Blanford. Palm weevil in British Honduras, Kew Bulletin, 1893, p. 42.

2 W. Fawcett. Report on the Coconut disease at Montego Bay. Bulletin of the Botanical Department, Jamaica, No. 23, 1891, p. 2.

3 A. Busck. Report of an investigation of diseased Coconut palms in Cuba. U. S. Dept. of Agriculture, Division of Entomology, Bull. No. 38, N. S., 1902.

4 F. S. Earle. Report on a trip to Jamaica. Journal of New York Botanical Garden, Jan. 1903.

5 Erwin F. Smith. Bud-rot of the Coconut palm in the West Indies. Science, N.S., Vol. XXI, 1905, p. 500.

directed to the bacteria present in the rotting tissues.[1] In the West Indian Bulletin for 1906 (Vol. VI, p. 307) there is a general review of the disease in the West Indies, and subsequent accounts of it have been written by Mr. W. T. Horne, Chief of the Department of Vegetable Pathology, Central Agricultural Station, Cuba,[2] by Mr. F. A. Stockdale, Mycologist of the Imperial Department of Agriculture, West Indies,[3] and by Mr. J. R. Johnston of the United States Department of Agriculture.[4] None of these have advanced our knowledge of the cause of the disease, and Mr. Horne records that many inoculations with organisms isolated from the diseased tissues have failed.

In the East bud-rot of coconuts is also widely distributed. It was described by Mr. T. Petch, Government Mycologist, Ceylon, in 1906, affecting a small area.[5] He considered it to be the same as the West Indian disease and attributed it to bacteria. He refers to correspondence with Portuguese East Africa in 1903 which indicates that the same disease occurs there. In the Philippine Islands bud-rot causes great damages in several localities, and an account of it was published in 1908 in the Philippine Agricultural Review.[6]

In 1906 the writer described a severe epidemic of disease in palmyra and other palms in the Godavari District of the East Coast of India.[7] In intensity this surpassed the outbreaks in most other countries, but it was confined to a comparatively limited area in

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1 J. H. Hart. Bud-rot disease of Coconuts, etc. Trinidad Botanical Department, Bulletin of Miscellaneous Information, Oct. 1905, p. 240.

2 W. T. Horne. The Bud-rot and some other Coconut troubles in Cuba. Estacion Central Agronomica de Cuba. Bulletin No. 15, English Edition, July 1908.

3 F. A. Stockdale. Fungus diseases of Coconuts in the West Indies. West Indian Bulletin, Vol. IX, 1909, p. 361.

4 J. R. Johnston. The Bud-rot of the Coconut palm. U. S. Dept. of Agriculture, Bureau of Plant Industry, Circular No. 36, July 1909.

5 T. Petch. Bud-rot of the Coconut palm. Circulars & Agric. Journal of the Royal Botanic Gardens, Ceylon, Vol. III, No. 15, April 1906.

6 Philippine Agricultural Review, Vol. I, No. 5, May 1908, quoted in The Tropical Agriculturist, Ceylon, Vol. XXXI, 1908, p. 555.

7 E. J. Butler. Some diseases of Palms. Agricultural Journal of India, Vol. I, p. 299, Oct. 1906. See also Memoirs of the Department of Agriculture in India, Vol. I, No. 5, 1907, p. 82, and Agricultural Research Institute, Pusa, Bull. No. 9, March, 1908, p. 21.

the Delta of the Godavari River. The cause of the disease was stated, as a result of a field and microscopic examination, to be a fungus belonging to the genus Pythium, a description of which, under the name Pythium palmivorum, was published in these Memoirs in February, 1907. Subsequent investigation (the details of which are given below) has confirmed this statement, and the disease has been several times directly produced in healthy trees by inoculating them with the fungus. A couple of cases of the same disease were found in Travancore on the West Coast of India in 1907, and there is little doubt that it was this fungus which was concerned in a coconut disease in the same State, mentioned in the Indian Forester in 1894 by Mr. A. M. Sawyer.[1] Up to the present the particular parasite which is the cause of bud-rot in India has not been met with in any other country. It is, however, premature to say definitely that the outbreaks mentioned above are all due to a cause different from that in India; there are as yet no published successful inoculations with any other organism, and the fact that Pythium palmivorum is not recorded in the diseased crowns does not altogether preclude its presence, since it cannot be easily detected except in the earlier stages of the disease. On the whole, it appears likely that the disease in the New World is due to a different parasite, while some at least of the outbreaks in the East may prove identical with that in India.

II.—Description of the area affected.

The Godavari River, rising in the Western Ghâts to the north-east of Bombay, crosses the Nizam's Dominions from west to east and bending southward falls into the Bay of Bengal about half way between Calcutta and Cape Comorin. At Dowlaishweram, 40 miles as the crow flies from the sea, it divides into two main branches, an eastern, called the Gautami Godavari, and a western, the Vasishta Godavari. About two-thirds of the way from Dowlaishweram to the sea, the Vasishta Godavari gives off from its left bank a third

[1] Quoted in Ferguson's "All about Coconut planting," Ceylon, 3rd Ed., 1904, p. cxxiv.

main outlet, known as the Vainateyam Godavari. The Delta proper, which begins at Dowlaishweram, thus consists of two large islands—Amalapur Island, bounded on the north-east by the Gautami branch and on the south-west by part of the Vasishta and the Vainateyam branch; and Nagaram Island, bounded on the north-east by the Vainateyam and on the west by the lower portion of the Vasishta branch. The term Delta is, however, extended for administrative purposes to include the tracts lying north-east and west of the river between Dowlaishweram and the sea, so far as is commanded by the irrigation system arising at Dowlaishweram.

The Delta, thus extended, comprises a portion of the administrative District of Godavari, *viz.*, the islands, and the mainland north-east of them, and a portion of the Kistna District, *viz.*, the mainland lying west of the islands. The administrative sub-divisions or "Taluks" included in this area are the following :—

GODAVARI DISTRICT.	"*Eastern Delta*,"	*i.e.*, the mainland north-east of the river. Most of Ramachendrapur and Cocanada Taluks.
	"*Central Delta*,"	*i.e.*, the islands. Amalapur and Nagaram Taluks.
KISTNA DISTRICT.	"*Western Delta*,"	*i.e.*, the mainland west of the river. Tanaku, Narsapur and Bhimavaram Taluks.

Three of the Upland Taluks, lying above the Delta, require also to be mentioned as they are referred to below. These are Rajahmundry and Peddapur, both of which belong to the Godavari District and consist of long stretches of stony waste alternating with wet land, and Yernagudem, belonging to Kistna, an undulating plain, broken by low ranges.

Communications within this area are good. Roads are numerous and the network of the canals in the Delta is largely availed of for boat traffic. The main channels of the river are of considerable size, often exceeding a mile in width, and communications across them are carried out by means of ferries, the only direct access from the right to the left bank being by the great railway and foot bridge, a mile and-three-quarters long, at Rajahmundry, six miles

above the head of the Delta, and the canal aqueduct and foot-way between Amalapur and Nagaram islands. In the monsoon the river rises considerably, submerging the smaller islands. The mainland and large islands are protected by massive bunds, but much of the low-lying paddy land is flooded by the local rainfall.

The Delta area is the most densely populated[1] and one of the richest of the Madras Presidency, north of the city of Madras. The bulk of the people, of course, live by agriculture, paddy being the chief crop, with various millets, pulses, sesamum, sann hemp, tobacco and sugar-cane as important subsidiary crops. The soil is mostly a heavy dark alluvium and is very fertile, but this fertility has only become available for supporting a large population since the completion of the irrigation system, one of the most remarkable in India, conceived and largely carried out by Sir Arthur Cotton between 1847 and 1852, as the rainfall is badly distributed. The mean temperature at Cocanada averages 82°F. with a mean range of 15°. The annual rainfall averages 40 inches for the Godavari District, but the first four months of the year are practically rainless and the south-west monsoon, which sets in in the middle of June and lasts until September, gives nearly two-thirds of the whole fall.

The natural forest vegetation of the Delta is scanty, no doubt as a result of close cultivation. The commonest species in much of the area is the palmyra palm, which is self-sown or planted along the divisions of the fields, in the villages and in waste spaces. Three other palms occur, the coconut and arecanut, which are grown as garden crops and the former of which is rapidly extending, and the

[1] The area and population of some of the Taluks are given as follows in the Imperial Gazetteer of India, Vol. XII, 1908:—

Taluk.	Area in sq. miles.	Population in 1901.
Ramachendrapur	296	220,356
Cocanada	294	213,758
Amalapur	506	277,445
Nagaram	137	103,619
Tanaku	371	238,758

date, which grows wild but is scattered. In the upland Taluks the palmyra is even commoner than in the Delta, in places reaching forest density; the coconut and arecanut are rare.

No other tree in these districts approaches the palmyra in economic value. A complete account of its uses would occupy many pages. An ancient Sanskrit poem professes to enumerate eight hundred and one! Every part of the tree is turned to account. The wood is universally employed in building construction in the villages. The base of the trunk, hollowed out, is used as a canoe in the numerous creeks in the Delta: it also forms an excellent water carrier for short lifts. Several different kinds of fibre are obtained from the leaves, stalks, fruit and interior of the stem. For one of these, extracted by beating from the leaf stalk, a large demand has sprung up recently, and it is extensively exported from the East Coast. The roots are used in medicine; the leaves for baskets, mats, fans, small buckets and a host of other every-day appliances, as well as for writing on. As a food plant it is of considerable importance, the parts eaten being the fruits both young and ripe, but chiefly the young shoot obtained by germinating the nuts. These are heaped together in seed-beds, covered with soil and left for three or four months, when the shoot is found to be from six inches to a foot in length. For a short period of the year these shoots form the staple food of some of the lower classes. From the inflorescence toddy is obtained, which is drunk both fresh and fermented, or made into vinegar, or distilled to make arrack.[1] It is also extensively used in the manufacture of jaggery or raw sugar, over 400,000 palmyra palms being tapped for jaggery in the Godavari District according to the Imperial Gazetteer. This is chiefly in the upland Taluks. Probably the greatest value of the tree after the production of toddy and the supply of food from the young shoots is in the provision of an ample and inexpensive material for thatching. Its leaves are almost the only thatch available throughout the Delta. A

[1] The Abkari revenue from toddy (including tree tax and rentals) averaged over 3 lakhs of rupees per annum between 1900 and 1903. This does not include revenue from country spirits (Godavari District Gazetteer, Vol. II, 1906, p. 42).

large tree will give from 25 to 30 leaves per annum, and as each house requires two or three thousand leaves and is thatched every three or four years, a village of 1,000 houses uses the produce of about 25,000 trees annually.

The palm is so common, grows so freely and requires so little attention, that the outbreak of a disease which destroyed large numbers did not cause much alarm amongst the people. Were it not that the more prized and tended coconuts were also attacked, it is doubtful if information of its existence would even yet have reached the Agricultural Department. That this attitude was mistaken there can be little question: the value of the tree is discounted by its abundance, but it is not too much to say that its disappearance would change the whole economic condition of the Delta. It is significant that in some of the severely attacked districts the price of the cut leaves has risen in the past few years from Rs. 3 to Rs. 9 or 10 per 1,000.

III.—First appearance and spread of the disease.

The disease is said to have first appeared in Addenkivarilanka, an island in the Gautami Godavari belonging to the Ramachendrapur Taluk, about 1890. From this it spread to both banks of the river and extended both along the banks and inland. Amalapur and Ramachendrapur, chief towns of the Taluks of the same names and situated respectively eight and eleven miles inland from the right and left bank of the Gautami near Addenkivarilanka, were reached about 1897. Pillanka (Cocanada Taluk), a village on the left bank, about twelve miles down the river, and Alamur, about eight miles up the river from the same place, are said to have been affected in 1898 or 1899. About 1902 the disease appeared at Vetlapalam, three miles south of Samalkota at the northern extremity of the Eastern Delta and extended into the upland Taluk of Peddapur. By this date in the Eastern Delta much of Ramachendrapur Taluk was affected and extension was going on into Cocanada Taluk and towards the upland districts near Peddapur. At the same time it is probable that all

the northern half of the Central Delta was affected, except towards the head of the Delta and near the sea. Three main lines of extension appear to have been followed in Amalapur Taluk:—One through Billakurru, Modekurru, Pulletikurru and tailing off towards Potavaram, Gannavaram, and the other villages along the Vasishta and Vainateyam branches of the Godavari; another through Ainavilli, Tottramudi and Thanalanka to the littoral villages south of the Gautami, such as Polavaram; and the third from Ainavilli through Vilasa and Amalapur to Perur and Allavaram. Nagaram island is known to have been affected in 1907, but the disease was slight and probably not of long standing.

In the Western Delta, in the Kistna District, the ryots themselves assign to the winter of 1903 the first appearance of the disease. This was in the Taluks of Tanuku and Narsapur which border the Vasishta river opposite to Amalapur and Nagaram. The date was fixed in their minds by the violent cyclones of October in that year which caused damage to many trees. However, a good observer[1] asserts that the disease must have been in some villages before 1900, judging from field appearances. The evidence here seems to suggest that it entered from Amalapur Taluk above Nagaram island, crossing the Vasishta in the direction of the first line of spread in this Taluk referred to above. By 1907 some 50 villages on this side of the river were affected, the majority very recently, and up to the beginning of 1909 fresh villages were continually being reached. The intensity of the disease on this bank of the Godavari is as yet less than elsewhere, and excepting for an area near the boundary between Tanaku and Narsapur Taluks and extending from the river to Aitampudi and Vallur few villages have reported more than scattered cases. The exact area affected in the Kistna District is not yet fully known, but an outbreak has occurred as far to the south as Masulipatam.

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1 Agricultural Inspector D. Balakrishna Murti, to whom I am indebted for valuable information, sketch maps and notes.

In the upland Taluks, besides the extension into Peddapur, scattered cases have occurred along the fringe of the Eastern Delta, particularly near Rajahmundry town and Anaparti and Biccavole villages. A small outbreak was reported at the end of 1908 near Chidipi and Kumaradevam in the upland Taluk, Yernagudem, of Kistna District, and at the end of 1909 cases were found in Katavaram (Rajahmundry Taluk) on the opposite bank of the river, ten or twelve miles distant from the nearest affected village in Rajahmundry. This is the only case so far reported of an apparently isolated centre of disease if we except the southward extension to Masulipatam, about which details are still wanting; and it is highly probable that it is due to infection from across the river.

Except these two localities and Masulipatam the whole of the rest of the area affected by the disease is continuous and is roughly circular in outline. It is quite clear both from the observations made in the field during the past four years and from information gathered from the cultivators, that the spread has occurred in a centrifugal manner from the locality in the Gautami Godavari first infected. Naturally the flow has been more rapid along some lines than others, and barriers such as the main channels of the river and tracts bare of palms have checked extension in some directions for a greater or less period; on the whole, however, the onset has been remarkably even and regular all round. Thus the eastern limit at Peddapur is some 30 miles from Addenkivarilanka, the southern in Nagaram Taluk about 24 miles, the western in Narsapur over 20 miles and the northern at Rajahmundry about 25 miles.

The rate of spread is, on an average, little over a mile a year, judging from the extension that has occurred in the area as a whole. In places, however, this is certainly exceeded. Thus an extension of between two and three miles occurred along the canal towards the sea near Kolanka, in the nineteen months from August 1905 to March 1907. Anaparti was the limit of the disease to the north in 1905, whereas three years later it had reached to Shrikistnapatam,

a distance of eight miles. From the same place or from Madiki infection spread to Rajahmundry, 13 or 10 miles respectively, in about two years. On the other hand, Vileasavilli is said to have been first attacked in 1906, while Amalapur town, 4 miles distant, was certainly infected before 1900. So also an observer noted that the village of Rajathapalapatnam was still free from disease in 1907, while Vetlapalam, an adjoining village,[1] had it since 1902. This sharp limitation of the disease at the border of the infected area has been several times noted. Near Kolanka, which was almost certainly attacked before 1900, the disease in one direction observed in 1907 diminished from severe (over 50 per cent. of deaths) to little (under 5 per cent.) in two miles, and two miles further on none could be found. Such cases as the last connect with those in which the onflow of infection appears to have received a check which shows some promise of being permanent. These are chiefly to be found towards the sea and are associated with sandy soils, but there is also some evidence that the drier upland tracts above the Delta oppose a barrier which may perhaps be found efficient. There is no doubt that there are at least two entirely distinct sets of factors controlling the extension. The first is meteorological and, other things being equal, the rate of spread will largely depend on the amount of rain, fog, dew and similar conditions. This will be more fully considered below. The second is biological and includes the little understood conditions which determine the virulence of the parasite, and still more, the susceptibility to attack of the victim. These seem to be in the present case closely connected with the influence of the nature of the soil on the palm itself.

Though, in a broad sense, the disease occupies a continuous area, it must not be supposed that it is uniformly distributed within this area. On the contrary, there is the greatest difference in the severity of the attack from village to village and even from field to field. Close observation confirms the view that the nature of the

1 It should be noted here that the term "village" is used in the sense employed by the revenue authorities, and denotes a certain area of land belonging either to one large village or to several hamlets. The first affected portion of the one village might therefore be perhaps a couple of miles from the nearest part of the adjoining unaffected village.

soil exercises an influence on the susceptibility of the palm to attack. Trees along water-courses and in periodically flooded localities, such as paddy fields, die more quickly and in larger proportion than in dry localities. Instances are numerous in low-lying land along the Gautami river and throughout much of the length of the Kousica water-course which traverses the Amalapur Island. In the villages of Ambajipeta, Gangalakurru, Pulletikurru, Modekurru and Isakapudi the deaths have been most numerous along this water-channel. On the other hand, little disease has been found in the light sandy soils of the sea coast villages. In the village of Nimekaya-Kottepalli, three or four miles from the sea and with sandy soil, no disease could be found in 1907; whereas Katrenicona, adjoining inland and with heavier soil, had lost a large number of palms. The black soils appear most to favour the disease. Naturally when the parasite reaches a spot where the palms are in a condition favourable to its attacks, it spreads rapidly and becomes greatly multiplied. As a result, neighbouring trees, even if not highly susceptible, are exposed to more intense and frequently repeated chances of infection than those at a greater distance. Hence, as a rule, around such localities the disease becomes progressively less severe as the distance from the severely diseased locality increases. Such minor centres of disease, around which the number of cases tails off, are common all over the district. A curious case was observed at Coringa at the Eastern limits of the disease in 1907. In a single "tope" or cluster of palms opposite the travellers' bungalow a number of deaths had occurred apparently a considerable time previously, while there was none in any other part of the village seen. The explanation of this was not found; for some reason, not immediately evident, the infectious matter which these trees harboured had not become disseminated to those near by.

Indeed, the actual mode of spread from tree to tree under natural conditions is not yet fully understood. It has been proved that direct application of the parasitic fungus which causes the disease to the crown of a healthy tree leads to infection of the latter.

Contact with a diseased leaf is sufficient to infect a healthy one. The disease spreads from leaf to leaf on the same tree chiefly by contact. It is, therefore, "contagious." How it spreads from one tree to another without contact, as it certainly does, is not so clear.

The following are the chief possible methods of spread from tree to tree: through the air; by human agency; by birds and insects conveying infectious matter on their bodies.

Most epidemic diseases which resemble the bud-rot of palms are spread through the air. The parasites depend for their propagation chiefly on spores, which are set free and are carried into the air by the wind. Alighting on healthy plants they germinate and produce infection. Such are the potato blight, cereal rusts and the like. Pythium palmivorum, which is very similar to the cause of potato blight, produces spores which would be just as capable of causing rapid spread of the disease as those of the latter, provided that they are formed in a position where the wind can easily reach them. This is not often the case, however, since spores have not been found on the surface of diseased crowns, except in the comparatively small number of cases in which the blade, or expanded portion of the leaf, is attacked. In the large majority of cases the seat of attack is the compact mass of leaf bases, the leaf-sheaths, which form a tubular covering to the top of the stem. Having entered the outermost of these, the fungus grows in towards the softer underlying ones and usually does not begin to produce spores until several have been penetrated. Spores have never been found on the hard outer sheaths, but usually occur between the softer inner ones at some distance from the surface. Here they are not exposed to the air and cannot serve as an effective means of propagation. In some cases, however, the young leaf-shoot at the apex of the crown is found to have been attacked in the portion which afterwards becomes the expanded "blade" of the leaf. This usually occurs while it is still small and hidden in the tube of leaf-sheaths, being the result of direct contagion from the latter. In a very few of these cases the parasite has been found still alive when the young leaf has pushed out into the air, and it is probable that in periods

of high humidity or during heavy dews spores would develope in this situation, freely exposed to the wind. A second condition in which there may be air-borne infection occurs when the tube of leaf-sheaths begins to disintegrate as an effect of the disease. In old cases the outer leaf-sheaths wither and fall away and eventually nothing is left but a bare pole. In these old withered sheaths no spores capable of germination have been found, but it is quite possible that they occur, and if this is so, they would be a means of dissemination. A third condition is the result of the stripping of the outer leaves for thatching and still more in some localities for fibre. In the operation the old leaf bases are torn away, and it is not uncommon to see leaf-sheaths that are still almost white from their internal position, exposed. In infected trees this must offer considerable opportunities for aerial dissemination of the spores. It is doubtful how far the above conditions are sufficiently frequent to account for the intensity of the epidemic. It appears that if this were a common method of spread, the area affected would by now be far greater than it is. Air-borne infection is always rapid and instead of the disease being confined to one small district, it would be found throughout the country. However, it is quite possible that the conditions mentioned above are sufficient to permit of a limited aerial dissemination while not enough to cause rapid extension of the infected area.

Dissemination of disease by human agency is particularly likely where, as in bud-rot, the diseased parts of the plant are habitually handled by persons who afterwards come into contact with susceptible portions of healthy trees. As already mentioned, each village uses the produce in leaves of a large number of palmyras for thatching. In addition a large number of trees are tapped for toddy and jaggery. Over 400,000 palms are tapped for jaggery in the Godavari District (mostly in the upland Taluks) according to the Imperial Gazetteer. For both these purposes the bulk of the palms in the district are climbed at intervals. It is the practice of the climbers to strip off the outer sheaths, both because they impede their operations and because they serve for fuel. Hence the inner

fresh, moist and softer sheaths are often exposed. In diseased trees this is just the position in which felted masses of the mycelium of the parasite are found. Fragments of the outer sheaths containing living mycelium no doubt often break off and remain on the person of the climber. The mycelium itself would readily adhere to his knife. It is easy to see that in repeating the operation in a healthy tree there is every chance of his successfully, if unconsciously, inoculating it with the parasite. There are indications in some places that the disease has followed lines of communication used by the people, particularly the ferries across the canals which intersect the district. These are no doubt used by the tappers and the matter would be explained if the infection is conveyed by them. In this district the coconut trees are not tapped for toddy and their leaves are rarely cut. Hence they are seldom climbed. Arecanuts are neither tapped nor are their leaves cut and when climbed it is only to remove the bunches of nuts, which project well away from the stem. It is possible that this explains in part the comparative immunity of these two species of palm.

The part played by insects in disseminating disease is now well known. Most of the cases recorded are in man or animals, malaria, tick fever, sleeping sickness and *surra* being instances. Flies are known to be important disease-carriers. A bacterial disease of potatoes is spread, according to Dr. E. F. Smith of the United States Department of Agriculture, a distinguished authority, by insects which convey the bacillus from plant to plant. In the present disease the parasite, being much bulkier than those concerned in the above cases, could only be carried by large insects. It so happens that palms are infested by several quite big enough to serve the purpose. The best known are the rhinoceros beetle and the palm weevil, the former of which is very common in the district. I have also seen as many as ten scorpions in the crown of a diseased Palmyra. Numbers of birds also frequent the tops of palms. The felted webs of mycelium which are sometimes found on the older sheaths may quite conceivably adhere to the feet of these and be carried from tree to tree. The beetles penetrate into

the heart of the crown and in diseased trees probably emerge from the pupal state within the disintegrating mass. Here they would be likely to come into contact with not only mycelium but spores which would adhere to their bodies. One or two observations bear on this point. The disease is noticeably severe around the huts of the "Madigas," a low class of Pariahs who eat the carcases of animals, and also near the huts of fishermen and other low castes. This may be due to the presence in such localities of the offal of animals, fish, etc., which would attract birds and insects. In the village of Ramachendrapur this fact was particularly visible. The rate of spread is, however, too slow to make it probable that birds play any considerable part, and, on the whole, though insects are probably responsible for some of the spread, their share is likely to be much less than that of the palm climbers.

While, therefore, the way in which infection is spread in individual cases has not been conclusively found, the methods considered above, particularly those connected with the stripping of the leaves by human agency, are probably sufficient to account for the conditions observed.

IV.— Species affected and course of the disease.

As already mentioned, four species of palm are common in the Delta, the palmyra (Borassus flabellifer), the coconut (Cocos nucifera), the areca (Areca Catechu) and the date (Phœnix sylvestris). Of these the first three are subject to the disease, while the date, so far as has been observed up to the present, is immune.

By far the greatest mortality has occurred amongst palmyras. Probably over half a million have been attacked within the affected area. Coconuts have suffered much less. In an enumeration of the diseased palms in the Mummidivaram Firka of Amalapur in 1907, less than 1 per cent. were found to be coconuts (46,527 palmyras, 455 coconuts). This disparity in numbers is not entirely due to the much greater quantity of palmyras than of coconuts actually growing in the area in question. In several places there are large gardens of coconuts surrounded by severely diseased

palmyras and yet containing few cases of the disease. In Muchumilli, a village of Ramachendrapur Taluk, the disease had been prevalent for about six years in palmyras before any coconuts were attacked. Clumps of palmyras in which over 50 per cent. of the trees have been killed are not uncommon, but nothing like this mortality has been found in coconut gardens. Owing to the way in which coconuts are cultivated in large gardens close together and without admixture of other kinds of trees, very favourable opportunities would appear to be afforded for the rapid spread of the disease from the first trees attacked to those surrounding. That this has not occurred may be due in part to the fact mentioned above that there is less opening for accidental inoculation by the palm climbers in coconuts than in palmyras, but probably depends in larger measure on a natural resistance presented by this species to the parasite. Only one experiment has been made which goes to prove that infection of coconuts is less easy than of palmyras. A coconut palm and two palmyras were inoculated on the same day. Examined after a month the former showed a small patch of infection about half an inch in diameter and penetrating less than half an inch of the thickness of the inoculated leaf-sheath, the inner surface of which had not been reached. There had been no obvious increase in the patch since the 8th day after inoculation. In the palmyras the progress was much more rapid, the inoculated sheaths showing large patches of disease which passed right through and were continued into the sheaths lying below.

Arecanuts are even less liable to attack than coconuts. The largest number found in any one village within a limited period was 17 at Billakurru in the second half of 1907. No experiments have been carried out to investigate the susceptibility of this species to attack. Arecanut gardens are not common and the disease in this palm is of little importance.

Palms of all ages are liable to the disease. The majority of cases are mature trees. In many cases young trees from three to five years old, growing under larger diseased trees, become attacked. It is the custom to plant the nuts along the bunds or dry banks

between the paddy fields, and the seedlings grow up beneath the older palms which line these bunds. In such cases it is probable that the vertical drip of water during rain carries down the spores to the young plants below. This would only occur in the cases in which the living fungus grows exposed to the rain. Further, successful infection would only occur if the spores reach a suitable part of the palm, such as an exposed inner leaf-sheath. Hence there is usually far less disease amongst the seedlings and young trees than in those which are large enough to be regularly climbed for leaves. Isolated young palms not growing near larger ones are seldom attacked ; isolated mature ones almost as often as those in clumps.

The intensity of the disease varies enormously in different places. Four hundred palmyras were found dead or dying in a single acre in one of the lankas close to where the disease is believed to have first appeared in the district. It was calculated that from 50 to 75 per cent. of all the palms within a mile of the village of Kolanka had succumbed by the end of 1907. In one place along the bank of the canal near this village the mortality increased from between 5 and 10 per cent. in August 1905, to between 60 and 70 per cent. in March 1907. In some fields of Ainavilli three-quarters of the palmyras were infected in June 1907. In one clump in this village 180 out of 236, in another 107 out of 140 had died. Of course, these are extreme cases, but there are many villages where it appears probable that not a fourth of the palms will soon be left unless the disease is checked.

The length of time taken to kill a tree can only be determined if the moment of first attack is known, and requires also the fixing of an arbitrary moment of death. In so large an organism as a mature palm, death does not occur all at once, excepting possibly under such circumstances as when a tree is struck by lightning. Ordinarily, death occurs "by inches," and when the apical bud and even all the leaves are killed, the stem and roots may still maintain their vitality for some time. Two periods may be selected as indicating the "death" of the palm in bud-rot. The first is

when the central shoot, formed of the innermost, partly expanded leaves, withers and dies. In the vast majority of cases this indicates that the heart of the leaf-bud has been reached and the apical point, which is the single locality in palms at which new leaves are formed, has been killed. Except in rare cases, to be described below, withering of the central shoot is a fatal symptom in palms ; no new leaves are produced ; the older ones gradually dry up ; no new food is manufactured, and though the tree lives for a time on food-reserves stored in the older tissues, these become eventually exhausted and total death ensues. A second period which may be taken as indicating "death" is when every leaf has withered and fallen and nothing is left but a bare pole. Long before this has happened all chance of recovery has disappeared, and it is therefore more satisfactory to select the first-mentioned indication in calculating the duration of the disease.

An experiment to determine this was carried out in 1908. Three rather young palms were inoculated on one of the outer leaf-sheaths, that selected being, as usual in the inoculations, not the outermost hard, dry sheath, but the clean moist one just below. They were kept under observation and after a little over five months the central shoot in two was found to be withering. The third still showed no external symptom and, as observations ceased soon after, its subsequent fate is not known. The other two were cut down and examined. One had 25 fully formed leaf-sheaths inside that inoculated, the other 30. In the first the infection, starting from the point inoculated, had penetrated twelve sheaths in immediate contact one beneath another. After the 12th sheath there appeared to be several quite free from infection spots. Then those in the centre of the crown, and the base of the central shoot itself, were severely attacked, the latter being reduced to a putrid mass Passing through several of the disease spots on the outer sheaths were the tunnels of the rhinoceros beetle, and these were continued on through some of the unmarked sheaths to the base of the central shoot. Either the parasite was carried in by the beetle, or the course taken by it from the 12th sheath

through several of those below escaped detection. The apical bud was involved in the rot at the heart of the crown and the tree was, therefore, beyond recovery.

In the second tree 10 sheaths were penetrated from that first inoculated. Then as before there were several apparently quite sound, while the centre of the bud was a rotten mass. Here again there were beetle tunnels running from the outer spots to the centre and opening a route for the parasite. In this case also the palm was beyond hope of recovery.

Hence in rather over five months the disease had penetrated about half of the radius of the bud (the outer sheaths are thicker than the inner) and had then jumped in some less direct fashion to the centre. Even granting that it grows at the same rate throughout, and is not assisted by insects, it should kill the tree in ten months. It probably grows much faster in the softer inner tissues than towards the outside, so that the time may be correspondingly reduced. Beetles are extremely common in diseased trees and may be attracted to them; these may lead to further shortening of the time by carrying the parasite rapidly through several sheaths. This is what appears to have happened in the two trees experimented upon. Therefore it seems safe to conclude that the disease is capable of killing moderately sized palms in from five to ten months from the date of first attack.

The period which elapses between the death of the central shoot and the loss of all the leaves of the crown is much longer. The central shoot of an outwardly healthy palmyra was noticed to become slightly pallid and less rigid than before between the 17th and 19th of December 1907. Sixteen days later the central shoot was quite withered and four of the inner leaves were yellowing. After twelve days more another leaf had turned yellow. Another tree observed in March 1907 when the central shoot had withered, was found nine months after to have lost only some of the central leaves, those towards the outside being still unwithered and firmly attached to the crown. Usually many months elapse before all

the leaves wither, and even then they take some time to fall away from the crown. From many enquiries it appears that three years or more may pass from the time when the central shoot dries up until all the leaves have fallen.

Similarly, the ryots stated that a coconut may be reduced from a fine, healthy, bearing tree to a bare pole in four years. It takes about three months for one of the central leaves to fall after it begins to wither. It has been noticed that in rainy or cold weather the leaves die and fall more slowly than during the hot dry parts of the year.

Recovery of diseased trees after the central shoot or even the greater part of the crown has withered sometimes occurs. In most of the cases observed this is due to the growing point having escaped injury. The parasite, passing in from the outer sheaths, may reach the central shoot at a point above its base and therefore well above the growing point. Usually when this occurs, subsequent extension down the central shoot takes place and the apical bud is destroyed. In some cases, however, the growth remains horizontal and the central shoot is cut across and breaks off. This is often accompanied by the death of several or even all of the expanded leaves of the crown. The appearance presented by such trees varies with the severity of the first attack. In extreme cases the whole of the expanded leaves of the crown are shed and the palm reduced to a bare pole, the top of which is flattened or even hollowed into a cup. From this rises, as if separately planted in this position, a small shoot of a few, usually much reduced and distorted, leaves, with their leaf-bases forming a narrow funnel, at the bottom of which is the growing point. One very characteristic case seen was that of a young palmyra only three feet high, which had lost all its older leaves, leaving the apex of the stem fully exposed and concave. From the centre of the depression rose the new shoot, consisting of three expanded small leaves and a fine central shoot of folded leaf-blades. In another large tree the same conditions were found, but the new shoot, seen from below, appeared to arise laterally from near the margin of the cup-shaped depression and its

leaves were much distorted. The lateral position may have been due to the new shoot pushing out before the older dead leaves had been cast, and being forced by these out of the direct line of growth. In other cases the older leaves of one side only were killed, those of the opposite side remaining healthy. The central shoot had broken off and had been replaced by a new shoot of small crumpled green leaves. Nearly all the instances so far noticed in which a new shoot has developed to replace that destroyed by the disease, have succumbed to a second attack in a comparatively brief period. In no case as yet observed has the new growth progressed sufficiently to bear fruit and in only one to form a crown of ordinary size. This is one of the indications that the parasite is capable of passing into a dormant condition and renewing its growth at a later period.

V.—Seasonal prevalence.

Much attention has been given to an attempt to ascertain the seasonal prevalence of the disease. The cultivators and tappers in several places declare that the deaths are most numerous from December to February, and least in the hot months, March to June. A study of the figures from the villages of Amalapur Taluk in which there are records of the number of new attacks observed periodically does not bear out the first part of this statement. It leaves no doubt, however, that the deaths are least numerous between February and July.

The following table shows the rainfall at Rajahmundry at the head of the Delta and the relative humidity at 8 A.M. at Masulipatam on the sea at the southern limit of the affected area :—

Average monthly rainfall in inches at Rajahmundry.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
0·14	0·25	0·32	0·91	2·93	4·84	7·09	6·67	7·15	6·45	1·98	0·15

AVERAGE MONTHLY RELATIVE HUMIDITY AT 8 A.M. AT MASULIPATAM.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
86·4	85·6	83·1	80·7	76·1	77·1	78·8	82·7	84·2	83·6	81·7	80·8

The coldest period of the year is from December to February. This is also the period of least rainfall, but the relative humidity is high in the two last months, there is a heavy condensation of dew at night, and the mornings are damp and foggy. From April to July is the period of highest temperature and lowest relative humidity, and although there is a moderate and increasing rainfall, there is little dew and the mornings are clear and bright. Temperature, rainfall and relative humidity all fall in November, after the receding monsoon, and before the cold weather fogs appear.

The following tables give figures of deaths amongst the palms observed periodically in a number of villages of Amalapur Taluk in 1907 and the first half of 1908. This period coincides with the origin of a widespread attempt to limit the ravages of the disease. It is probable that, as a result of these operations, the deaths towards the end of the period were less numerous than they would otherwise have been. This does not, however, invalidate the conclusions to be drawn from the figures, as the higher figure in many cases follows the lower.

I. Villages showing most deaths when humidity is high and least when it is low.

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Gangalakurru	Feb. 10th to Sept. 2nd '07.	153	Sept. 3rd '07 to Feb. 8th '08.	345	Feb. 9th to June 19th '08.	89
Bandarulanka	Jan. 31st to Sept. 8th '07.	68	Sept. 9th '07 to Feb. 23rd '08.	125	Feb. 24th to June 15th '08.	68
Nadupudi ...	Feb. 10th to Aug. 6th '07.	1	Aug. 7th '07 to Feb. 1st '08.	88	Feb. 2nd to June 26th '08.	21
Amalapur ...	Jan. to June '07.	631	June '07 to Jan. '08.	1,053	Jan. to July '08.	235

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Vanne Chintalapudi.	Jan. 29th to Aug. 18th '07.	62	Aug. 19th '07 to Feb. 26th '08.	153		
Irusamanda ...	July 20th '07 to Feb. 29th '08.	104	March 1st to July 4th '08.	16		
Vadapalem ...	Sept. 9th '07 to Jan. 21st '08.	91	Jan. 22nd to Sept. 3rd '08.	13		
Mosalapalli ...	Feb. 10th to Aug. 9th '07.	30	Aug. 10th '07 to Feb. 3rd '08.	80		
Nalamilli and Janupalli.	March 31st to Aug. 5th '07.	35	Aug. 6th '07 to Feb. 11th '08.	117		
Palagummi ...	March 8th to Aug. 7th '07.	18	Aug. 8th '07 to Feb. 2nd '08.	133		
Avidi ...	Sept. 7th '07 to Jan. 23rd '08.	797	Jan. 24th to July 2nd '08.	85		

Within the period of greatest mortality there is sometimes evidence of a secondary period of diminished virulence. This varies somewhat in time but occurs after the south-west monsoon has ceased. The subsequent recrudescence is probably responsible for the idea already mentioned that the greatest mortality occurs in the cold weather.

II. Villages showing in diminution after the Monsoon and a recrudescence in the cold months.

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Anatavaram ...	July 29th to Sept. 17th '07.	267	Sept. 18th to Nov. 9th '07.	58	Nov. 10th '07 to Jan. 23rd '08.	164		
Siripalli ...	May 3rd to Oct. 20th '07.	173	Oct. 21st to Dec. 22nd '07.	16	Dec. 23rd '07 to Feb. 1st '08.	61		
Magam ...	April 22nd to Sept. 17th '07.	624	Sept. 18th to Dec. 18th '07.	96	Dec. 19th '07 to Jan. 28th '08.	143		
Nedunur ...	Aug. 28th to Oct. 7th '07.	312	Oct. 8th to 30th '07.	33	Oct. 31st to Dec. 14th '07.	246		
Vilasa ...	May 15th to Oct. 13th '07.	554	Oct. 14th to Dec. 30th '07.	78	Dec. 31st '07 to Feb. 4th '08.	162		
Isakapudi and Potavaram.	May 9th to Aug. 28th '07.	362	Aug. 28th to Nov. 25th '07.	93	Nov. 26th '07 to Mar. 10th '08.	238		
A. Vemavaram	June 4th to Aug. 13th '07.	123	Aug. 14th to Oct. 22nd '07.	192	Oct. 23rd '07 to Jan. 3rd '08.	39	Jan. 4th to Feb. 8th '08.	191

This secondary diminution after the rains is not by any means universal, and there is no indication of a cold weather recrudescence in the following cases, where the maximum mortality was at the end of the monsoon.

III. Villages in which the maximum mortality occurred at or near the end of the Monsoon.

Village.	Period.	Deaths	Period.	Deaths	Period.	Deaths.
Bhatnavilli ...	April 10th to Aug. 23rd '07.	64	Aug. 24th to Oct. 24th '07.	193	Oct. 25th '07 to Feb. 2nd '08.	80
Mungonda ...	May 12th to Aug. 25th '07.	37	Aug. 26th to Dec. 4th '07.	116	Dec. 5th '07 to March 12th '08.	39

In a good many villages the deaths appeared to occur fairly regularly between August and February as the following show :—

IV. Villages in which the deaths are evenly distributed between August and February.

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Uppalaguptam	Aug. 28th to Nov. 15th '07.	81	Nov. 14th '07 to Jan. 7th '08.	60	Jan. 8th to Feb. 6th '08	53
Narendrapuram	June 10th to Aug. 28th '07.	118	Aug. 29th '07 to Jan. 9th '08.	244	Jan. 10th to March 4th '08.	117
Modekurru ..	June 6th to Sept. 1st '07.	245	Sept. 2nd to Dec. 8th '07.	192	Dec. 9th '07 to April 25th '08.	188
Machavaram ..	Feb. 1st to July 3rd '07.	341	July 4th to Oct. 12th '07.	561	Oct. 13th '07 to Feb. 20th '08.	568
Udumudi ..	Aug. 30th to Dec. 13th '07.	42	Dec. 14th '07 to Feb. 26th '08.	57		
Polivela ...	Oct. 2nd to Nov. 22nd '07.	718	Nov, 23rd '07 to Jan. 28th '08.	969		
Tondavaram ...	July 21st to Oct. 31st '07.	56	Nov. 1st '07 to Feb. 7th '08.	65		

In a few cases the figures show little evidence of a seasonal period of maximum intensity throughout the year.

V. Villages which do not show any marked period of maximum intensity.

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
K. Pedapudi ..	April 28th to Sept. 3rd '07.	200	Sept. 4th to Nov. 30th '07.	126	Dec. 1st '07 to Feb. 11th '08.	144	Feb. 11th to June 26th '08.	164
Mukkamala ...	May 11th to July 21st 07.	20	July 22nd to Oct. 9th '07.	49	Oct. 10th '07 to Feb. 28th '08.	22	Feb. 29th to May 29th '08.	30
Pulletikurru ...	June 1st to July 17th '07.	58	July 18th to Oct. 3rd '07.	405	Oct. 4th to Dec. 21st '07.	266	Dec. 22nd '07 to May 5th '08.	334
Chiratapudi ...	May 15th to Aug. 19th '07.	157	Aug. 20th to Nov. 22nd '07.	100	Nov. 23rd '07 to March 26th '08.	180	March 27th to April 28th '08.	133

To sum up the question of seasonal prevalence it is clear that, with few exceptions, the deaths are more numerous in the villages of Amalapur Taluk in the months from August to February, than from March to July. This is in close relation with the relative humidity of the two periods, and applies equally well to the other affected Taluks. There is a less close relation with the rainfall. In the monsoon, especially in its second half, the mortality appears to reach its maximum, but it is high also in the cold weather months of heavy dew and ground fogs, when there is usually little rain. A distinct diminution in the mortality is observable in a good many instances after the cessation of the monsoon, followed by the cold weather recrudescence. This is not general, since a few cases can be quoted where no diminution after the rains occurred. Still it was sufficiently marked to have attracted attention from the supervisors in charge of the work of checking the spread of the disease.

VI.—Symptoms.

As already mentioned, the disease is usually confined in its earlier stages to the large fleshy leaf-sheaths which encircle the apex of the palm, just below the expanded crown of leaves. The outermost

of these, exposed to the air, are usually brown and dry and are moreover partially hidden by the cut bases of older leaves, and in coconuts by loose fibrous layers. Hence it is not possible to detect the spots on the outer sheaths in standing trees, and as a rule the first indication visible without felling the tree is the withering of the central shoot or of one of the expanded leaves. In the great majority of cases it is the central shoot that withers first. This is undoubtedly because the heart of the bud, which consists of the young unexpanded leaves and their bases, is very soft and full of sap, while the sheaths towards the outside are progressively harder and less juicy. Hence the parasite grows through these from the outside without, as a rule, much lateral expansion, and forms on them only isolated spots or patches, not large enough to cause the leaves above to die from stoppage of food supplies and loss of support. As soon as it reaches the young soft tissues of the unexpanded leaves it spreads with great rapidity and soon destroys the centre of the bud. The cluster of partially expanded leaves in the centre of the crown is next affected, and in this stage the presence of the disease can be detected from below. Less often the first leaf to show morbid changes visible from below is one of those fully expanded. It is merely a question of accidental circumstances favouring the growth of the parasite in particular places. The affected leaves first turn pale and then wither, becoming dry and yellowish brown in ten or twelve days.

Besides the leaf-sheaths the parasite also occurs on the leaf-blades in certain cases, and even on the petioles. One of the figures on plate III shows the characters of the attack on the blade. From the symmetrical nature of the spots on the segments of the leaf, as well as from several cases actually observed, it is clear that the attack occurs while the young blade is still folded within the bud. In some of these cases the tissues above the spots die and fall away, and the blade appears as if cut across at the level of the disease. Very few cases of attack on the petiole have been seen. In one an expanded leaf was bent and hanging down from about the centre of the petiole, where a large, soft, brown and sunken spot passed right

through its thickness. In another there was a spot affecting only about half the breadth of the petiole, the rest and the blade above being still green and healthy.

The apex of the stem is sometimes also affected. In one case observed the inner part of the crown was destroyed and the young wood below the diseased leaf-bases was soft and discoloured with pink and brown patches. These contained living mycelium of the parasite.

The spots on the leaf-sheaths vary much in size, from only just visible to six inches or more across. In the inner sheaths they are white at first, becoming brown or reddish later on. On the outer sheaths they may eventually be black. A very early result of the attack is the collapse of affected cells, which leads to the spots being sunk below the level of the surface of the rest of the sheath (see photograph on plate III). The margin of the depression is usually bounded by a raised rim. The early spots are dry and hard and may either be quite free from any external parasitic growth or covered with a white mycelial web. Later on, particularly in the soft heart of the bud, the diseased areas are invaded by numbers of saprophytic organisms, bacteria, moulds and insect larvæ, and the whole is converted into a foul-smelling rotten mass.

On the leaf-blades the spots are usually smaller than on the sheaths, not often exceeding an inch in diameter on individual segments. They are straw-coloured in the centre and bounded by a broad dark-brown margin.

The flow of toddy from diseased palmyras is checked soon after the death of the central shoot. In a case observed a palm was marked for tapping by the Abkari officers in January 1908, after the toddy drawer had climbed and carefully examined it and pronounced it healthy. The central shoot was found withered in the first week of April, but the tree was still being tapped. The quantity of juice obtained was only about one-half that from healthy trees, and the quality was bad. It is the practice to mix the juice from such trees with that from healthy trees, as it is otherwise unpalatable.

In coconuts the fruit is affected. None of those formed after the symptoms of the disease are visible externally, develop properly; they drop one by one while immature. Those formed somewhat earlier may ripen, but are often of inferior quality.

VII.—Description of the Parasite.

Pythium palmivorum belongs to a genus of the most primitive group of the fungi, the Phycomycetes or alga-like fungi. The characters of this genus have been sufficiently described in a previous number[1] of this series, and need not be considered in detail here. It is composed partly of aquatic and partly of terrestrial forms, several of which are parasitic on other plants. The terrestrial forms are nearly all soil-dwellers, two only, the present species and P. Indigoferæ Butl., inhabiting the aerial parts of plants. The description of P. palmivorum, previously published, requires to be amplified as a result of further examination.

The body of the fungus consists of branching threads or "hyphæ" forming in the aggregate a web or "mycelium," which may be entirely buried in the palm tissues or may be partly superficial on the surface of the leaf-sheaths, where it frequently develops so as to form a thick white felt over the disease-spots.

The hyphæ, which are very irregular, measure on an average 5μ ($\frac{5}{1,000}$ millimetre) within the tissues but are often larger, especially in the superficial felted mass where they may be up to 8μ. They are continuous hollow threads, not being divided by cross-walls, except in rare cases, particularly near where the organs of propagation are formed. Within the tissues they occur in the intercellular spaces, and also force their way between adjacent cells, becoming irregularly compressed and contorted in so doing. They are nourished exclusively from the living cells of the host-plant, into which they send fine prolongations known as "haustoria" or suckers.

[1] Butler, E. J. An account of the genus Pythium and some Chytridiaceæ. Memoirs of the Dept. of Agric. in India, Vol. I, No. 5, 1907.

The ends of the young germ-tubes from germinating spores possess the power of boring through the wall of the sporangium. Penetration is effected by the exudation of a solvent liquid, which is almost certainly, from the analogy of other known cases, a cellulose-dissolving enzyme, from the tip of the germ-tube. This was clearly observed in cases in which zoospores germinated within the sporangium, as in those figured in plate IV, fig. 15. Figs. 15*a* and *b* show a spore which failed to escape through the mouth of the sporangium, and after swarming for a time within it, came to rest and surrounded itself with a wall as usual. A couple of hours later it had germinated and the germ-tube had reached the opposite wall of the sporangium. The apex of the germ-tube now swelled up and became closely appressed to the wall. A vacuole occupied its tip. Some time after, it was noticed that an area of the wall considerably larger than that in contact with the tip of the germ-tube had undergone an alteration, which was visible in profile as a gelatinous swelling in which the sharp double contour of the rest of the wall was lost (fig. 15*a*), and from above (surface view) as a light, extremely transparent spot (fig. 15*b*). The swollen portion of the wall was clearer than the rest. Actual penetration was not observed in this case, but fig. 15*c* shows the ultimate condition from another similar case. The same power of penetrating cell walls is possessed by the haustoria, which are able to enter the parenchymatous tissue cells, but are not found in those of the vascular bundles. The ordinary vegetative hyphæ are, however, unable to enter the host cells, but grow exclusively between them ; in other words, their tips do not excrete a cytase.

When a leaf is first infected, the infection may arise from germinating spores or from vegetative mycelium. The latter is what occurs when a leaf-sheath is infected from another in contact with it, as happens regularly during the progress of the disease towards the centre of the crown. In this case it is probable that penetration occurs through the stomata, which are numerous on the outer surfaces of the leaf-sheaths. In tracing the disease inwards through

successive leaf-sheaths, it is easy to find spots in the innermost layers where the parasite has only penetrated a portion of the sheath thickness, the spot being visible on the outside but not on the inside of the sheath. Sections through these show the hyphæ passing through the stomata. Some of these appear to be hyphæ of entry, though the fact is extremely difficult to prove. Others are hyphæ of exit, as is shown by branching taking place just outside the stoma. Hence it is evident that the parasite, after invading a sheath from the outside, may send back branches through the stomata to the outer surface, and it is this fact which makes it difficult to be certain that entry occurs along the same road. In a few cases the mode of entry or exit shown in plate V, fig. 11*a*, where a hypha engages in the thickness of the cuticle and passes along the vertical walls of the epidermal cells, was seen, but whether such hyphæ were going in or coming out could not be decided. The rarity of these cases, compared with those in which hyphæ pass through the stomata, makes it very probable that the latter is the ordinary mode both of entry and of exit.

When the first infection is from zoospores no evidence is available as to the route followed. As already mentioned, the germ-tube can bore through cellulose walls, but this does not imply that it can penetrate the cuticle. The fact that the internal mycelium is purely intercellular does not preclude the possibility of entry directly across the epidermal cells, for in Phytophthora Colocasiæ Racib., a common parasite in India, the germ-tubes penetrate the leaf frequently in this manner, though below the epidermis they are strictly intercellular. The only reason for believing that zoosporal infection in Pythium palmivorum occurs through the stomatic openings is that, in many sections examined, no case was seen of hyphæ passing across the epidermal cells, though some of the spots sectioned had resulted from inoculation with zoospores. Still some cases were seen in which hyphæ occupied the cavities of the epidermal cells as shown in plate V, fig. 11*b*, and this seems to show that these cells offer less resistance to the entry of the parasite than those of the parenchyma.

Excepting the bundles and the bands of sclerenchyma, which are numerous, the parasite is found in all parts of the leaf, reaching to the bundle sheaths on the one hand and to the inner walls of the epidermis on the other. The haustoria arise from any part of the hyphæ and are numerous. They are found in both parenchyma and epidermis and are straight or curved finger-shaped processes, which rarely branch.

Haustoria of Pythium palmivorum.

1. In thin-walled parenchyma. 2. In an epidermal cell. 3. Club and button-shaped haustoria with cellulose cap. 4. Branched haustorium.

After the internal mycelium has become copious and has accumulated a sufficient store of food from the contents of the host-cells, branches from it emerge through the stomata to the surface. When the next underlying sheath is closely in contact, it may be infected by these hyphæ without the formation of any visible superficial mycelium. Often, however, there is sufficient space between the sheaths (especially when the attacked area becomes depressed) to allow of the formation of a considerable mass of white web-like mycelium, which is one of the distinctive characters of the species. No other species of Pythium known to me, nor any of the allied genus Phytophthora, forms such a dense mycelium as the originator of palm bud-rot. Under these hyphal masses it is common to find hyphæ emerging from the majority of the stomata. The superficial hyphæ differ but little from those within the leaf, except that they are sometimes considerably thicker (plate IV, figs. 1 and 2). On them and not on the internal mycelium, the reproductive organs

of the parasite arise. These are of two types, sporangia and resting conidia.

The sporangia are formed terminally on the main branches of the mycelium or on short or long stalks borne laterally on these. They are produced in great numbers in favourable conditions, such as when a piece of leaf-sheath with a spot containing vigorous internal mycelium is incubated in a moist atmosphere for 24 hours. Then a dense growth of hyphæ occurs from the stomata, the hyphæ being irregularly branched and usually terminating in sporangia, while others may arise on lateral branches lower down (plate IV, fig. 3). The superficial growth in these cases is woolly, from free branching of the emergent hyphæ, and is partly erect, partly creeping. Sporiferous hyphæ may stand up nearly $\frac{1}{4}$ inch from the surface of the leaf. In watch-glass cultures from young infected leaves, long threads consisting of a number of hyphæ have sometimes extended from the leaf to the sides of the glass, and on these lateral sporangia are common. Old mycelial webs immersed in water for 24 hours often give rise to numerous sporangia on short stalks arising from any part of the mycelium (plate IV, fig. 4). As is the case generally in Pythium, definite conidiophores distinct from the rest of the mycelium, such as are found in most of the Peronosporaceæ, do not occur; the sporangia are formed on the tips of ordinary hyphæ or on lateral branches from them.

The sporangia are very variable in size and shape. In the previous description they are given as 50 by 35μ on an average (extremes 38 to 70 by 33 to 42), but smaller ones than this are not uncommon in poor cultures. The shape is typically piriform, the attachment being by the broad end. Irregular shapes, such as those figured in plate IV, fig. 5, are common, and the attachment is sometimes lateral (plate V, fig. 10*a*). When ripe, the narrow end is always papillate, the papilla varying from a small knob to a protrusion $\frac{1}{4}$ the diameter of the sporangium; it is broader than is customary in the genus.

Germination of the sporangia takes place very rapidly when sown in water, within half an hour under favourable conditions. Four

types of germination occur, which though distinct enough in appearance, are all modifications of the one process. The most characteristic, though by no means the most common, is that which is practically universal in the genus Pythium and which is, as pointed out in the general account of the genus previously referred to, the only absolute mark of distinction of this genus from Phytophthora. In this case the apex of the papilla swells up into a very thin gelatinous vesicle into which the protoplasm of the sporangium passes in a uniform granular mass. Within the vesicle it segments to form a number of zoospores, which develop cilia and move ever more vigorously in the confined space, until the vesicle wall ruptures and the spores swim off in all directions (plate IV, figs. 6 and 7). In some cultures prolonged search was necessary to find instances of this type of germination; in others it was quite common. On the whole it is less frequent in the cooler months of the year than that next to be described.

This is simply an incomplete form of the last, in which the vesicle is either not formed at all, the apex of the papilla dissolving, or if formed, ruptures almost immediately. Segmentation into zoospores occurs within the sporangium, and is complete or nearly complete before the papilla opens. As soon as an opening forms, the protoplasm streams out and breaks up at once into free swimming zoospores (plate IV, fig. 8). Owing to the pressure of the mass within the sporangium it is not possible to distinguish the individual zoospores before escape, but it is evident that they must be fully formed before the rupture of the papilla since they separate at once after escape, and also because as soon as pressure is reduced by the extrusion of part of the sporangial protoplasm, the remainder may segment while still inside and emerge as fully formed mature zoospores. This is the type of zoospore formation habitually met in Phytophthora, and in several cases the palm parasite would have been taken for a Phytophthora, had not prolonged search revealed an occasional instance of the first type of discharge. Intermediate types between the two are sometimes found. Thus in one case about three-quarters of the protoplasm emerged in a mass surrounded by a vesicle,

which then dissolved, and the mass at once broke up into individual zoospores, as did the remaining one-quarter still within the sporangium at the moment of rupture of the vesicle. Sometimes the vesicle is formed in the ordinary way but the zoospores are almost mature when they leave the sporangium and the vesicle early dissolves to liberate them.

The third mode of germination is a regression on the last. The zoospores mature within the sporangium and when the papilla opens are unable, from one cause or another, to escape. After a variable period of free movement within the sporangium they come to rest *in situ*, round off, become clothed with a wall and germinate by germ-tubes which pierce the sporangial wall (plate IV, fig. 9). Here also intermediate cases between this and the last type occur. Sometimes a portion of the protoplasm escapes in a mass and breaks up at once into zoospores which swim away in the water. Blocking of the tube of exit from any cause then prevents the remainder from escaping, and this segments within the sporangium to form zoospores which ultimately germinate *in situ* as just described. Even when complete segmentation within the sporangium occurs, some of the resulting zoospores may creep out through the opening while others fail to escape.

The last type of germination is that in which zoospore formation is entirely suppressed, and the unopened sporangium germinates by putting out one or several germ-tubes in the manner of a conidium. Conclusive evidence was given in the previous account of the genus to show that this is merely a further reduction on the zoosporal type. It is one of the main adaptations to a terrestrial life which the semi-aquatic Phycomycetes have developed in the process of establishing themselves on land. Successful dissemination by zoospores requires the presence of water in bulk, and is unsatisfactory in species which are only intermittently irrigated. Germination by germ-tubes merely requires a moist atmosphere, and has entirely replaced the older zoospore method in the higher fungi. In Pythium the transition is clearly seen, and it is almost equally maintained in Phytophthora, all the species of which still preserve the

zoosporal method, while most can also germinate by germ-tubes. In the higher Peronosporaceæ the formation of zoospores gradually disappears and direct germination becomes the rule. Plate IV, figs. 10 and 11, show direct germination of the sporangia of Pythium palmivorum. In many cases the germ-tube is single and arises from the papilla at the apex of the sporangium (fig. 10). In others a number of germ-tubes arise scattered over the surface (fig. 11). Usually the growth of the germ-tubes is limited, and secondary sporangia are early formed at their apices and those of their branches (fig. 10 *b. c. d.*).

The zoospores are of the ordinary Pythium type, and measure from 8 to 10 μ after they come to rest and assume a spherical shape. They germinate rapidly (within an hour) by one or sometimes two germ-tubes, which may grow to a considerable length and branch (plate IV, fig. 12). Sometimes they fail to germinate and break up into a granular mass (plate IV, fig. 13). In a few cases two or more spores remain united after leaving the sporangium. These double zoospores are marked by their large size, and instead of becoming spherical at the end of their period of swarming, assume an oval or irregular shape, and are surrounded by a single wall (plate IV, fig. 14). Germination in these cases is quite normal. In one instance the whole contents of the sporangium escaped in a mass and moved about with an irregular jerky motion, eventually coming to rest and forming a common wall. Germination was not seen.

The second spore form is that which was termed an oospore in the previous description. Further examination has shown that it is not a sexual product and is not contained in an oogonium, but is a distinct "resting" variety of conidium. At certain periods of the year, *e.g.*, in the hot dry weather in March, only this spore form has been found. In other cases it has been found on the same mycelium as the sporangia, and there is no doubt of its being a stage of Pythium palmivorum. The resting spores are spherical, thick-walled, often yellowish when old and are formed singly at the ends of usually large hyphæ (plate V). Intercalar ones have occasionally been observed (plate V, fig. 7). They measure from 25 to 40 μ

in diameter, the wall being up to 4 μ thick. Irregular shapes are sometimes met with (plate V, figs. 8 and 9).

The stalk hypha is sometimes exactly like those of the vegetative mycelium, sometimes variously dilated and irregularly branched (plate V, figs. 2 to 5). In many cases it is septate some distance below the spore, the appearance resembling the hypogynal antheridia found in P. de Baryanum, P. Artotrogus and other members of the genus (plate V, figs. 1, 2 and 5). In other cases branches from the stalk hyphæ or from neighbouring ones closely encircled the spore (plate V, figs. 2 and 4), and it was these appearances, as well as the general resemblance to an oospore, which led to its being described previously as a sexual spore. However, many cases have since been seen in which it was formed terminally on a simple unseptate stalk entirely free from adjacent hyphæ and with no trace of anything that could be construed as an antheridium (plate V, fig. 6). This, together with the absence of any differentiation of the contents into an oospore lying within an oogonium, quite precludes its being construed as a sexual formation, and it must be considered as a much more highly developed equivalent of the resting conidia of P. de Baryanum. The germination has been previously described and is invariably by a germ-tube, which may branch and always bears terminal sporangia after a short growth (plate V, fig. 10). The period during which these spores preserve their vitality is not known, but is likely to be at least some months.

No trace of true oospores has been discovered during the period that the parasite has been under observation. A sufficient number of cases has been examined to make it probable that if they occur they must be rare and are not likely to be of any practical importance in the life of the species.

From the observations made at different times of the year it has been noticed that sporangia are usually found on the attacked leaves only at the periods of considerable rainfall or heavy dews. They were found in June, July and August without much difficulty, less often in September. In March none could be found in one locality where a rather thorough search was made. Resting conidia are less

common in the rainy period, but very numerous in the hot dry months. Sterile webs of mycelium occur at all times of the year and may often be induced to form sporangia by placing in water for 24 hours. More often than not it is in this form only that the fungus exists on the palm sheaths excepting immediately after heavy rain or dew.

Numerous attempts were made to cultivate the parasite artificially without success. The media used were boiled slabs of palmyra leaf-sheath, plantain, potato, bread, boiled prune and grape juice and sugar solution, and boiled flies. Zoospores, sporangia and mycelium were used for separate inoculations. In no case did the slightest growth of Pythium palmivorum take place. The fungus is probably an obligate parasite as are nearly all parasites that feed exclusively by haustoria and do not send their hyphæ into the cells. This fact has been noted by Matruchot and Molliard for the genus Phytophthora[1], and is perhaps of wide application.

VIII.—Inoculations.

The following is a detailed account of some of the successful inoculations carried out. Owing to the locality of the disease being about 1,000 miles by rail from his head-quarters, only series III below was carried out by the writer personally. The others were done under his directions and in most cases controlled by subsequent microscopic examination of spirit specimens. Series I was done by his assistants, Mr. S. N. Mitra and Babu R. Sen; Series II, V and VI by Mr. Sundararaman, Mycological Assistant to the Government Botanist, Madras; Series IV by Messrs. Mitra and Sundararaman conjointly.

I. The material used for inoculation was young living mycelium, bearing sporangia and resting spores. It was obtained from the surface of fresh clean spots on an inner sheath of a recently attacked palmyra, and was microscopically pure. The trees inoculated

[1] Matruchot L. et M. Molliard. Sur le Phytophthora infestans. Annales Mycologici, Vol. I, p. 543, 1903. H. Klebahn has, however, cultivated on artificial media his Phytophthora Syringæ which is exclusively intercellular except its haustoria. (Krankheiten des Flieders, Berlin, 1909.)

were five palmyras from five to seven feet in height (to the base of the crown), two of which were in low land under shade and three in a drier situation, unshaded.

The inoculations were made by removing the outer leaf-sheaths until a white clean sheath was exposed, and applying a portion of the material to the surface. The surface of the sheath was not artificially sterilized, but was probably sterile, as the sheaths fit so closely over one another that there is ordinarily no cavity left between. The instruments used were flamed. The method does not differ in any way from that commonly adopted in dealing with obligate parasites such as the rusts and mildews, as in the absence of artificial cultivation of the parasite it is not possible to secure rigorously sterile conditions.[1] After inoculation the last removed leaf-sheath was replaced in position and firmly bound in place. The wrappings were watered at intervals for two days to prevent premature drying of the material.

On the 4th day after inoculation one of the trees was examined. A discoloured patch was visible at the point where the material had been placed. A day later the infected area was marked off from the rest of the sheath by a marginal line, inside which were several isolated spots of a deeper brown than the rest. Two days later the other trees were examined, and a depressed area, marked by brown spots of different sizes and surrounded by a raised edge along which ran a reddish-brown bounding line, was found to occur in all, at the place where the inoculations were made. The outer sheaths that had been replaced over the infected ones had also become attacked and from this time onward the point inoculated could be detected, without unfastening the wrappings, by means of the spots which penetrated them. By the 8th day one sheath was found completely penetrated, the depressed area being larger on the inside than on the outside. This was seen by lifting the free edge of the sheath without removing

[1] The nearest approach to such conditions has been obtained by the late Professor Marshall Ward working with grass rusts. The ingenious method adopted is described in the Proceedings of the Royal Society, Vol. LXIX, No. 458, 1902, p. 451, but is obviously inapplicable to plants of the size of those under consideration.

it from the tree. Next day a surface growth of mycelium had appeared near the edges of some of the spots. On the 11th day the sheaths were removed one by one from the inoculated trees. In each case the parasite had passed completely through three sheaths (including that inoculated) and had entered the fourth sheath but not reached its inner surface. In two of the unshaded trees insects and moulds had collected on the spots and a wet rot had developed. In the other three the spots were dry and permeated only by the mycelium of Pythium palmivorum. Microscopic examination showed that the characters of the mycelium and its relations in regard to the host cells were exactly as described above. Sporangia and resting spores were borne on the surface mycelium on the second and third sheaths.

II. Two young trees were inoculated in the same manner as in the last experiment. On the 10th day the free edges of the inoculated sheaths were pulled back so as to see those next below. In one the next sheath was only slightly affected and no further progress occurred, probably because the premature disturbance of the first sheath caused drying of that below. In the other, large patches covered with a superficial mycelium were found on the next sheath below the point inoculated. This sheath was also pulled back and was found with small spots on its inner surface where penetration had occurred. One small unsunken spot occurred on the surface of the third sheath. In this case growth of the parasite continued and five days later the sheaths were cut away one by one. Two more sheaths were found penetrated by the parasite, and the next sheath below was marked by a small spot on its outer surface. In 15 days, therefore, the parasite had passed through five sheaths and infected the sixth.

III. The material used was obtained from a recently infected unopened leaf in the heart of the bud of a diseased Palmyra, which was placed for 12 hours in a covered sterile watch-glass with a few drops of boiled water. A good growth of mycelium extended to the sides of the glass and bore quantities of sporangia. Some of this was picked off on sterile needles and sown in sterile water ; in about

half an hour a copious zoospore formation took place. The zoospores, without any mycelium, were washed off into a sterile covered watch-glass and used for the inoculations. The material in this case was likely to be absolutely pure, since it was obtained from an aerial growth consisting exclusively of Pythium palmivorum, and since some of it, used to inoculate sterile culture tubes of palmyra slabs, gave no growth of foreign moulds.

The inoculations were made on three palmyras varying from 6 to 12 feet in height exactly as described above, except that drops of water bearing only zoospores were used.

On the 4th day one of the trees was examined and a slight discolouration without any depression found at the inoculated point. On the 6th day all were examined and showed brownish discoloured patches at the seat of inoculation, the colour being much deeper than in the one examined two days earlier. A copious exudation of gum was taking place from the inoculated patches. Two days later all the trees showed the marginal boundary line, and two were developing isolated dark brown spots on the discoloured area. By the 10th day the affected area was distinctly depressed and the margin raised up. On this day one of the inoculated sheaths was removed and that next below was found slightly discoloured, where the parasite had reached it after penetrating through the first sheath. After 4 weeks all the sheaths were removed and it was found that 3, 4 and 6 sheaths respectively (including that inoculated) had been attacked, in the line towards the centre of the bud. In one case a lateral extension of 8 inches was found on the sheath next below that inoculated.

IV. The material used was a fresh growth of mycelium bearing ripe sporangia. It was obtained by placing pieces of a young palmyra leaf-sheath, cut as aseptically as possible and with superficial mycelium, for about 18 hours in a sterilized Petri dish. By this time the previously sterile mycelium had given off numbers of fertile hyphæ with sporangia ready to germinate on the addition of water.

The trees were two palmyras and a coconut about 8 feet high, and the inoculations were made as before. After 8 days the inoculated sheaths of two of the trees were examined. In the coconut one large brown spot, about $\frac{1}{2}$ inch in diameter, and two lightly coloured smaller spots were found on the inoculated area. In one of the palmyras there was a large irregular slightly discoloured blotch. The wrappings were again replaced and not removed until a month from the time of inoculation. Little progress had occurred in the coconut palm, the large spot being now much sunken but scarcely larger than when seen before and it had not penetrated the sheath. In the palmyras the inoculated sheaths had been penetrated and those next below infected but not completely penetrated.

V. The material used was a drop of water containing zoospores from a slide on which sporangia had discharged.

The inoculation was made by opening the folds of a very young leaf in the apical shoot of a young palmyra, pouring in the drop, closing the folds and securing them by a thread.

After 14 days the inoculated leaf was cut and examined, and brown patches were found extending through about 10 of the folds. These were sectioned and found to contain hyphæ of Pythium palmivorum.

VI. The material was a small mass of mycelium from the superficial web of Pythium palmivorum from a diseased palm.

The inoculations were made as in the last experiment, on the still folded leaf in the bud of two young palmyras.

The inoculated leaves were cut and examined after 28 and 30 days respectively. Brown spots extended from the inoculated place through three or four folds, and on sectioning hyphæ were found passing through the stomata.

The above cases show that the disease can be produced by artificial inoculation. In the first experiment the number of sheaths

penetrated was three and-a-half in eleven days; in the second, 5 were penetrated in 15 days. Both these were done in the period of heavy monsoon rains. In the third, carried out in late September in bright sunny weather at the end of the south-west monsoon, there were only 3, 4 and 6 sheaths respectively, penetrated in 28 days in the three trees inoculated. In the 4th, which extended from November 10th to December 10th, the progress was still slower. The experiment quoted on page 238 showed that in two trees 10 and 12 sheaths had been penetrated in the period from March 24th to September 10th, which includes the driest and wettest months of the year. Hence it would appear that the progress of infection may be rapid in the rains but gets slower as the amount of rain diminishes and the temperature falls in the cold weather. It is probable that in the last quoted experiment, most of the extension took place subsequent to the onset of the monsoon in June, as there is a great deal of observational evidence to show that little occurs ordinarily in March, April and May.

IX. — Dormant condition of the Parasite.

The difference in the rate of progress of the disease in inoculated trees leads us directly to the consideration of cases which suggest that the parasite may pass into a dormant condition for a greater or less period and resume growth again. It was frequently observed during the earlier period of the campaign undertaken to destroy all diseased trees in the affected area, that fresh deaths continued to recur after a locality had been cleared of dead and dying palms. At first these were believed to be new infections conveyed in some manner unknown. Then it was noticed that there was a difference in the distribution of these cases as compared with outbreaks which were undoubtedly due to fresh infections, as when a village became attacked for the first time. In the latter case the deaths were in groups or often in one small part of a village only, indicating spread from one or a few early attacked trees. The deaths in villages that had been one or more times cleared of all outwardly diseased trees occurred scattered throughout the cleared area. In Amalapur

village such scattered cases continued to recur with the greatest persistence. In two small areas kept under continuous observation which had been cleared of a large number of diseased trees in November 1906, five subsequent inspections up to September 1908 yielded fresh cases. It was impossible that outwardly diseased trees could have escaped cutting on these occasions, since the plots were close to the road through the village which was frequently traversed by those in charge of the work. Similarly outside infection was scarcely to be thought of, for the whole village, as well as those adjoining, had been very thoroughly and repeatedly worked over, being the head-quarters of the Taluk where the campaign was prosecuted with the greatest energy. Examination of several of these cases showed that the outer leaf-sheaths bore unmistakable evidence of previous infection, the old brown spots on the outer sheaths being split and dried up. The sheaths of at least two years' leaf supply often remain attached to the tree, and there was every reason to suppose that some of the spots seen on this and other occasions on the outer sheaths may have been two years old. It is now believed that such old spots may serve for a considerable time to re-start an active phase of the disease. This is probably brought about through the tardy germination of resting spores, which have several times been found in the dried mycelial webs on the surface of old spots. The mycelial growth resulting from the germination of the resting spores is small and soon terminated by the formation of one or two sporangia. The spores from these would settle on the sheaths in contact and might succeed in penetrating them, whereas from their small number and entangled position in the old sheaths there would be little likelihood of the sporangia being carried to other palms before germination.

Several cases of arrested penetration have been seen. In one, a previously healthy palm was found with fresh spots on the outer sheaths on the 6th July. On October 23rd it was cut and spots found extending through 4 sheaths, after which the spread had apparently stopped. In another, some 10 sheaths had been penetrated but all the spots were old and the innermost appeared to have

ceased to grow some considerable time previously. A cut tree was found to have succumbed to a second attack, the first having penetrated nearly to the bud, killing the outer leaves, and then stopped. Subsequently 5 healthy leaves had been put out and a recommencement occurred in the rains, and these and the central bud were killed. In this case it was calculated that the dormant period had lasted four or five months.

A number of observers have noticed that palms which show symmetrical spots of disease on the expanded leaf segments always die sooner or later. It has previously been explained that these spots are caused by penetration of the tube of leaf-sheaths at a position above the growing point, the central bud of folded leaves being reached through its enclosing sheaths. The subsequent death of the crown, occurring sometimes months afterwards, would be readily explained by assuming that extension recommences from the spots on the inner sheaths and ultimately reaches the growing point.

All the above affords considerable ground for believing that the parasite can pass into a dormant condition actually within the bud, and can recommence activity at a later date, progressing until the growing point becomes involved and death ensues.

X.—Measures for controlling the disease.

Suggestions for an organised attempt to stamp out the disease in the infected area were made to the Government of Madras in April 1906, and are given almost in full in the paper on Palm Diseases in the Agricultural Journal of India, October 1906, referred to above. As a result, a sum of Rs. 5,000 was provided for a trial of the measures proposed in a limited area. These were sufficiently promising to justify larger proposals, which were given effect to in the middle of 1907. Since that time a large campaign, having as its objects to limit the disease to the area already invaded and to stamp it out within that area, has been in continuous operation. Since January 1910 it is believed that every part of the infected area is being systematically dealt with.

The trial measures were confined to three firkas, one in each of the taluks of Amalapur, Ramachendrapur and Cocanada. A young Indian Mycological Assistant, Mr. S. Sundararaman, from the Government Botanist's Office, Madras, was placed in charge of the work. He was provided with three Revenue Inspectors, subordinate Indian officials of the Revenue Department, one being posted on special duty to each of the selected firkas. The first step in the work was the issue of a circular to all the villages in the firka, calling for a return of the number of affected trees within each village area. Each tree counted by the village officers and village servants was marked with lime. The Revenue Inspector then arranged to visit in turn every village reporting the presence of the disease. On his arrival a fresh examination was made, and a number of professional palm climbers (toddy drawers or "Idigas," of whom a large number live in the Delta) sufficient to carry out the work required, were hired. Some of these were provided with small axes and employed in cutting away the tops of diseased palms. Others were engaged in applying Bordeaux mixture to the leaf-sheaths of all palms within a radius of about 25 yards from those diseased. At the end of the day's work coolies were employed to gather together and burn the cut crowns. As a rule no difficulty was encountered in obtaining fuel for burning the crowns, as their own leaves usually afford sufficient for the purpose. The workers quickly became expert, and with a little experience it was found that a good man would cut off the tops of about 15 palms or apply Bordeaux mixture to about 35 in a day. The axes were provided by Government, and the Bordeaux mixture required for each day's work was prepared the evening before by the Revenue Inspector. It was served out as required, after thorough stirring, into small pots which, with a bunch of rags for applying it to the sheaths, was hung to the back of the climber's belt. Each tree took about a pint for effective covering of the sheaths. It was found that the Inspector could supervise the work of about 20 climbers, but it was not always easy to recruit the full number required in the village under treatment, and later on climbers were frequently imported from other villages in the district.

The data obtained as a result of the work in the Coringa Firka of Cocanada Taluk in three months, from December 1906 to March 1907, are given below. The results in the other firkas were comparable. In Coringa Firka there are 35 Government villages of which about 20 reported the presence of the disease. During the first three months of the operations about 12,000 palms were cut and about 45,000 treated with Bordeaux mixture. The cost, including pay of supervising establishment, wages of coolies and cost of materials but excluding pay of the Mycological Assistant, was about Rs. 900 (£60). It was estimated that the cost of treating the palms with Bordeaux mixture, including all charges except supervision, was one pie ($_1{}^1{}_2$ anna) per tree, which accounts for Rs. 234-6, leaving Rs. 665-10 for cost of cutting 12,000 palms and supervising charges. This gives about ·9 anna per tree cut.

In reviewing these trial operations it was evident in the first place that no permanent good could be expected from them,[1] owing to their small scale and the continued inflow of infective matter from the surrounding untreated area. They, however, gave very valuable indications of the practical difficulties to be encountered, afforded a reliable basis for estimating the cost of any further extension of the work and showed several directions in which improvement could be effected.

The whole of a firka was found to be too large an area for one party to work through. Since at the time of first treating a village, a number of palms were certain to have been infected so recently as to show no outward symptoms and were sure to remain undetected, it was evident that subsequent visits would have to be made to discover and destroy these when they developed sufficiently to be visible from the ground. As already pointed out the trees are not dangerous to their neighbours in these early stages, and one or two return visits of this nature would, it was anticipated, be sufficient to account for all. The parties required for these secondary operations, and the time taken in each village in carrying them out, would

[1] The writer was not consulted when they were planned.

not, it was estimated, be considerable. It was suggested that the first return visit should be made a month from the completion of the first operations, and three or four months later any subsequent infections should be removed. As Coringa Firka took altogether nearly four months for one party to work through once, it was clear that further staff was required for the secondary operations.

The chief difficulty was found to be that of securing that a really careful search should be made for diseased trees. The village officers were very unreliable in this respect and it was difficult to impress on the executive staff the vital importance of not letting a single diseased tree escape. It was, and has been up to date, necessary to struggle constantly with the tendency of the Revenue Inspectors to settle down in a village, cut the trees in its immediate vicinity, and leave the surrounding country unexplored.

Little attempt was made in the beginning to secure the co-operation of the villagers themselves. From the middle of 1907 considerable efforts were made in this direction. A vernacular pamphlet was distributed broadcast throughout the whole of the infected area, and the permanent staff were constantly urged to use every opportunity for securing independent action. The results were, it must be admitted, most disappointing. Owners of coconut gardens in many places cut out their dead trees, but would not do so as long as there was any chance of getting a crop. Very few palmyras have been cut by the cultivators themselves. The apathy of the Indian cultivator in such matters is too well known to need comment.

It was found advisable to abandon the treatment of healthy palms with Bordeaux mixture. It was thought wise to concentrate all efforts on the cutting out and burning of diseased tops, since this was likely to give the surest results and a larger area was likely to be freed from infective matter in a given time. The chief reason, however, was that the treatment with Bordeaux mixture appealed much more to the imagination of the ryots than the destruction of diseased palms, owing to their natural antipathy to destroying any-

thing that might be conceivably of the least use to them afterwards. This might have led to very serious consequences by diverting their attention from the really essential part of the measures taken.

It was recommended that the work should be concentrated in Amalapur Taluk at first. This Taluk comprises five firkas and bordered on non-infected tracts and on the sea for a considerable portion of its periphery. For the rest it was separated from infected parts of Ramachendrapur and Nagaram Taluks by large branches of the Godavari, across which reinfection was not likely to be frequent. The area of the Taluk is 506 square miles, of which about four-fifths were infected in 1907.

Accordingly an enlarged campaign was commenced in Amalapur Taluk in June 1907. The executive staff consisted of eight Revenue Inspectors and Assistant Revenue Inspectors. The general control of the staff was entrusted to Mr. A. A. Ferguson, an Assistant Collector of the Indian Civil Service. In addition to Mr. Sundararaman, three Supervisors were employed, two, Mr. S. N. Mitra and Babu R. Sen, from the Mycological Laboratory, Pusa, and one, Agricultural Inspector Balakrishna Murti, from the Madras Department of Agriculture. Later in the year Revenue Inspector K. Lakshmana Rao, who proved exceptionally capable, was promoted to the position of Supervisor and Messrs. Mitra and Sen returned to Pusa. The Supervisors were each assigned a definite area within which they were expected to travel about, check the work of the working parties and call attention to any neglected cases or any recrudescence of the disease in villages already worked over. They were also empowered in cases of urgency to employ labour independently for cutting out diseased trees.

The difficulties encountered during the operations were numerous, but were generally surmounted successfully, where this was possible, by the efforts of the staff. One of the chief, however, has always been present to a greater or less extent ; this is the difficulty of securing permanency in the staff itself. Every Department

in India is normally short-handed and any new call for a staff outside of ordinary work at once introduces complications. The Agricultural Department, which should naturally have taken charge of the entire work, was of new creation, its organisation was incomplete and it was impossible to find the staff required for the work. Even the Supervisors at first appointed, had to be taken off after some time owing to urgent demands for their services elsewhere. Mr. Ferguson had much other work connected with the District administration. The Revenue Inspectors were continually being transferred, as they are all borne on one common establishment and a vacancy in a higher grade may lead to a number of minor promotions and changes. It was most trying to find that a man who had got well acquainted with the work was suddenly transferred and a raw new-comer put in charge of one of the ranges. I wish to acknowledge invaluable aid in smoothing difficulties received from the Collector of Godavari, Mr. J. A. Cumming, I.C.S.

The recruitment of the staff of palm climbers and coolies was often difficult, particularly at the busy seasons of the agricultural year. Sometimes this was got over by importing labour from outside. Eventually the daily pay was raised from 4 to 5 annas, a rate slightly above current labour rates, and this was on the whole effective.

It was sometimes difficult to get individual diseased trees cut. Old cases are reputed dangerous to climb as they may be hollow and rotten ; very thin ones are difficult to climb. These were generally cut at the ground level, but cutting from the base was not generally practised because of the great hardness of the wood at this part. Trees on which banyans grow (not uncommon in the Delta) are held sacred and will not usually be cut by the people of the village in which they occur. Usually, however, outsiders have no scruples in this respect, and the villagers have no objection to a man from another village being imported to cut such trees.

It required continual watchfulness to prevent the leaves of diseased crowns being carried away for fuel and thatch. A certain

amount of infective matter has no doubt been preserved from burning on this account, but the staff were continually impressed with the importance of securing the destruction of the entire crown. The danger of dissemination rapidly disappears when the cut leaves are exposed to the heat of the sun, as is the case with most that are used in the villages. In rainy weather or where supervision was slack, the cut crowns were sometimes left to accumulate for some days. This was a serious fault and every effort was made to check it. The two important difficulties all through have been, however, the difficulty of obtaining the co-operation of the ryots, and the difficulty of securing a reasonably permanent staff.

By December 1907 the whole of the infected area of Amalapur Taluk had been worked over, and all the old cases cut out. The first return visit had been paid in most villages and the second was in progress. This set free a portion of the staff, and the work was accordingly extended to Ramachendrapur Taluk by the beginning of 1908. A considerable recrudescence in Amalapur Taluk in January and February 1908 detained about half the staff south of the Gautami until the hot weather. By the 1st April, 1908, the returns showed that 177,000 palms had been cut in Amalapur Taluk since the beginning of the operations, and probably over a quarter of a million in the whole area. The total cost incurred up to date had been about Rs. 18,000 (£1,200) including pay of establishment except the supervisors.

In April 1908 Mr. Ferguson was transferred, and as his successor Mr. W. K. Green, Special Deputy Collector, did not join until July, the work suffered through want of supervision. Supervisor Balakrishna Murti was taken off in July and Sundararaman in October. Three parties remained on in Amalapur, and were fully occupied in dealing with the effects of the wide-spread recrudescence which had occurred in the early months of the year. The greater part of the staff was concentrated in Ramachendrapur where a large area had to be dealt with.

In October 1908 Mr. Green introduced a new system for carrying on the operations. The experience in Amalapur had shown, especially in the period from January to July 1908, that it was not possible with the staff available to ensure that new cases were cut out sufficiently rapidly to prevent them becoming dangerous to surrounding healthy trees. So long as it was believed that the disease progressed rapidly and continuously within the palm crown from the time of infection to the death of the tree, the previous arrangements appeared to afford sufficient safeguards against the danger of leaving any considerable number of diseased trees uncut long enough to enable them to infect others. The simultaneous occurrence of a large number of deaths early in 1908, together with other observations referred to on a preceding page, led to a strong probability about this time, which afterwards became practically a certainty, that the disease frequently does not progress continuously, but becomes arrested after penetrating some way into the bud. It is probable that arrest occurs in a considerable number of trees over a large area at about the same time, from some common cause such as temperature or dryness of the air. In the same way when conditions of growth again become favourable, general recrudescence may occur, and a large number of deaths, too large to be rapidly dealt with by a few travelling parties, appear simultaneously.

It became necessary, therefore, to endeavour to devise a system under which simultaneous operations over a large area would be possible. This Mr. Green did by transferring the onus of removing dead trees in each village from the special staff to the village officers. This relieved the whole of the staff of 8 Revenue Inspectors from all work, except that of inspecting each village, checking the trees reported cut by the village officers and making the necessary payments for hire of palm climbers and coolies.

Under this system, which is still in force, the village officers of every village reporting the disease are required to submit monthly progress reports showing the number of trees cut in each village during the month. They also maintain registers showing the survey

numbers[1] in which diseased trees occurred and the number in each. When a Revenue Inspector comes round (an effort is made to inspect each village once a month) the register is produced and a certain percentage of the entries checked by an actual visit to the survey numbers indicated. Payment is then made at a fixed rate of $\frac{3}{4}$ anna per tree cut to the village officer.

Delays naturally occurred in the introduction of the new system. A circular had to be issued to all the village officers, but as these are sometimes illiterate and often careless, its purport had to be explained by the inspecting staff. By January 1909 most of Ramachendrapur and Cocanada Taluks had begun regular cutting and the village officers were reported to be co-operating fairly well. In Amalapur, however, they were slow to perform their share of work and Rajahmundry and Nagaram were worse. In March 1909 only 260 villages out of 566 in the infected Taluks of Godavari District sent in reports, in April, 327.

From April 1st, 1908, to March 31st, 1909, about 140,000 palms were cut out in the Godavari District at a total cost of Rs. 14,109 (£940).

In the face of considerable difficulties Mr. Green continued to effect an improvement in the work of the village officers. He was given powers of reprimand and of inflicting small fines directly in cases where the village officers were persistently remiss in seeing that trees were cut. This gradually told and in August 1909, 432 villages out of 566 in the infected Taluks of Godavari submitted reports. By December the number had risen to 518 and by the beginning of this year cutting was progressing practically simultaneously over the whole of the infected area in Godavari. The total number

[1] For land record and revenue purposes each field in a village receives a number on the village map. It is therefore easy to find any particular field and check the trees cut. Later on the stems of cut trees were consecutively numbered, to avoid any risk of the same tree being entered and paid for more than once.

of trees cut from April 1st, 1909, to March 31st, 1910, was 84,107. The cost was not available at the time of writing.

The period during which operations have been in progress in the different parts of the Godavari up to the beginning of 1910 may be roughly summarised as follows :—Amalapur and parts of Ramachendrapur and Cocanada a little over three years ; the rest of Ramachendrapur over two years and of Cocanada about 18 months ; Peddapur about two years ; Rajahmundry about 18 months ; Nagaram one year. At the same time it must be understood that equal activity has not been shown in all districts. Outlying ones have often neglected the work, and the inspecting tours of the writer and of the controlling staff have proved that several, perhaps many, villages have allowed dead trees to accumulate for months.

In the following table, which gives the figures of cut trees paid for month by month from December 1908 to January 1910, the figures do not accurately indicate new cases of disease since the preceding month. In some villages the accumulations of several months may be cut out in one effort as a result of actual or threatened punishment, and will all appear in one month's return. In others, through slack inspection or connivance of the inspecting staff, the cutting of a large number of trees may be spread over several months. Cases were seen by the writer in Nagaram Taluk in February 1910 where, although some of the diseased palms in a village had been recently cut, others that were of some months' duration had been left standing and would go to swell the totals of succeeding months. Hence though the table gives a general, it does not give an exact, statement of the number of fresh infections in the reporting villages each month. It is, of course, to be borne in mind when considering the monthly totals for the whole area, that the number of villages reporting increased month by month to more than double the original figure. This does not imply that new villages were infected, but merely that an increasing number took up the work.

Statement showing the number of cut trees paid for by Revenue Inspectors monthly from December 1908 to January 1910 inclusive, in the Godavari District.

Months.		Nagaram Taluk (51 villages).		Amalapur Taluk (171 villages).		Ramachendrapur Taluk (117 villages).		Cocanada Taluk (105 villages).		Rajahmundry Taluk (91 villages).		Peddapur Taluk (31 villages).		Total of the six Taluks (566 villages).	
		No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	Villages.	Trees paid for.
December,	1908	37	*	38	3,029	71	3,603	19	2,011	31	294	13	Included in the figures for Ramachendrapur Taluk.	209	8,937
January,	1909	15	183	41	4,780	34	4,224	15	4,872	68	31	5		178	14,090
February,	,,	48	432	21	3,987	70	3,484	7	2,629	65	0	3		214	10,532
March,	,,	48	168	14	4,531	115	2,455	26	64	57	66	...		260	7,284
April,	,,	51	215	10	3,609	101	2,241	74	2,469	65	0	26		327	8,534
May,	,,	17	215	52	1,149	73	2,639	59	1,449	24	184	5		230	5,636
June,	,,	8	97	76	3,531	58	1,185	49	1,290	13	50	11		215	6,153
July,	,,	6	†0	91	1,488	56	1,739	34	599	13	0	31		231	3,826
August,	,,	51	†0	81	1,932	117	1,531	90	879	67	135	26	10	432	4,487
September,	,,	49	†0	87	814	117	3,038	96	952	62	136	19	...	430	4,940
October,	,,	51	14	77	2,662	115	4,261	96	928	64	57	31	132	434	8,054
November,	,,	51	208	110	4,093	117	3,711	102	1,452	57	97	30	...	467	9,561
December,	,,	51	153	146	4,672	117	2,353	105	1,386	69	76	30	112	518	8,752
January,	1910	51	56	148	3,275	117	2,475	102	1,882	73	43	28	...	519	7,731
															108,517

* Figure not available.

† No Revenue Inspector available.

The account of the operations so far refers exclusively to the Godavari District. The existence of the disease in the Kistna District, across the Vasishta Godavari from Amalapur, was reported

by Mr. Ferguson in March 1908. Under the Indian administrative system each district forms a separate unit, the officers of which have no standing in the next district. It was accordingly necessary to move the Government of Madras to extend the operations into the Kistna District. The Collector of Kistna, however, reported in December 1908 that the attack in his district was due to a beetle and not to a fungus. The writer received very definite information early in 1909 that the disease was undoubtedly the same in both districts and was rapidly extending in Kistna, and in conjunction with Mr. Green submitted proposals for the staff and expenditure required to deal with it. These proposals were sanctioned late in the year and Mr. Green placed in charge of the work in both districts. It was not until January 1910 that the organisation was complete and cutting operations actually commenced.

The total staff employed in January 1910 was as follows :—

Godavari District.

4	Revenue Inspectors	on Rs.	40/	per mensem.
5	„	„ „	30/	„ „
9	Peons	„ „	7/	„ „

Kistna District.

5	Revenue Inspectors	on Rs.	40/	per mensem.
4	„	„ „	30/	„ „
9	Peons	„ „	7/	„ „

Special Deputy Collector's Staff.

1	Clerk	on Rs.	20/	per mensem.
1	Head peon	„ „	9/	„ „
3	Peons	„ „	7/	„ „

In the Kistna District a considerable number of villages are infected in Tanaku and Narsapur Taluks which adjoin Amalapur and Nagaram Taluks of the Godavari. Yernagudem Taluk is slightly affected, and there is at least one severe outbreak in Bunder Taluk near Masulipatam. The disease is also reported with some doubt from Gudivada Taluk. The total area affected is probably small as compared to that in the Godavari. It is impossible at present

to gauge the importance of the extension to the south. The infection of Tanaku, Narsapur and Yernagudem is clearly an extension from the infected Taluks of the Godavari and the total area affected is not believed to be large. There is a great jump however from these Taluks to Bunder and Gudivada, and the intervening country will have to be gone through very carefully to search for some continuous line of extension. There is a considerable coastal traffic between the Godavari and Masulipatam and the possibility of infective material having been conveyed by human agency by sea must be taken into account. The rapidity with which the disease has spread, when once it passed south of the Godavari River and out of the area where control measures were in progress, is testimony that the writer's first estimates of its dangerous possibilities were not exaggerated.

It is now necessary to review the effect of the operations on the spread of the disease. The first fact that stands out is that since the end of 1908 there has been no increase in the infected area in the Godavari District, excepting the small area at Katavaram of reinfection from Yernagudem across the river in the Kistna District, referred to on page 229. The exact limits of the area infected to the north and east have been well known since early in 1908 and there can be no doubt on this point. This check is not due to any scarcity of palms, for northwards from the Godavari there is a great area of palm country extending into Vizagapatam and to the base of the Eastern Ghâts. Taken in conjunction with the extension which has been steadily progressing in Kistna where no control measures were in force this result must be attributed to the operations. It was not until after the middle of 1908 that active measures were in force along the whole of the northern and eastern boundaries of the infected area, and the almost immediate check of extension in these directions must be considered as satisfactory.

The second point to be considered is to what extent there has been a diminution in the disease within the area of the operations. At first sight it would appear from the monthly figures of trees cut in the six infected Taluks of the Godavari given on page 274 that the diminution has been slight. As already stated in connection with the

STA[T] VILLAGES OF AMALAPUR TALUK, GODAVARI DISTRICT.

NAME OF VILLAGE	NUMBER OF TREES CUT							AVERAGE PER MONTH.			
Amalapur ..	Between	May	1909	and	January	1910	698	77	for	9	months
Ainavilli ..	,,	April	,,	,,	,,	,,	121	12	,,	10	,,
Nedunur ..	,,	,,	,,	,,	,,	,,	533	53	,,	,,	,,
Avidi	,,	,,	,,	,,	,,	,,	259	26	,,	,,	,,
Billakurru ..	,,	,,	,,	,,	,,	,,	319	32	,,	,,	,,
Polivela ..	,,	,,	,,	,,	December	1909	1,432	159	,,	9	,,
Ryali	,,	May	,,	,,	January	1910	286	26	,,	,,	,,
Vakkalanka ..	,,	April	,,	,,	,,	,,	268	27	,,	10	,,
Vanapalli ..	,,	,,	,,	,,	,,	,,	228	23	,,	,,	,,
Vadapalem ..	,,	,,	,,	,,	,,	,,	43	4	,,	,,	,,
Pedapudi ..	,,	,,	,,	,,	,,	,,	53	5	,,	,,	,,
Nadupudi ..	,,	,,	,,	,,	,,	,,	62	6	,,	,,	,,
Irusamanda ..	,,	,,	,,	,,	,,	,,	126	12	,,	,,	,,
Gangalakurru ..	,,	,,	,,	,,	,,	,,	80	8	,,	,,	,,
Idarapalli ..	,,	,,	,,	,,	,,	,,	30	3	,,	,,	,,
Average per month for all the villages				...				473			

hich it was thought wise to remove at the return visit.

table, this is really due to a large number of villages having been persuaded to adopt systematic cutting, and not to any failure of the measures adopted to check the disease. The proof of this is to be found in a consideration of the number of trees cut periodically in the villages where cuttings have been more or less regular for a considerable time. The writer has been unable to find any village which does not show a fall in the number of trees cut periodically, where figures are available from a fairly early period in the campaign.

The villages in the accompanying table illustrate this point. They have been selected absolutely at random, being in fact most of those for which cutting figures up to or later than April 1908 happened to be filed in the Mycological Laboratory, Pusa, with one or two others for which figures were readily available. The total number of palms growing in these villages is so large that the fall in the numbers cut cannot be due to the cutting operations having removed any appreciable proportion of the trees liable to infection.

The above figures show a fall to little more than one-third in the average number of trees cut monthly, the mean interval between the middle of the two periods selected being about 18 months. The fall in Peddapur and Rajahmundry Taluks along the Northern limits of the infected area was more marked and led Mr. Green to report in July 1909 that the disease was practically extirpated from these Taluks. This was an over-sanguine view but still the number of new cases in these two Taluks is now small. Even allowing for the fact that, as stated in the discussion of the figures given in the table on page 274, the monthly figures do not always accurately represent the actual new cases every month, the error applies equally to both periods, and there is no doubt that a marked fall has occurred in the intensity of the disease in the Godavari.

The factor which has prolonged the operations and added enormously to their difficulty is one which was not foreseen when they were first started. This is the existence, which the writer now believes to be unquestionable, of latent infection. How long the parasite may remain dormant within the bud is not known, but there is

evidence to show that the period may be as much as two years. It is not likely to be much more and consequently, if the operations are persevered in, all dormant cases must ultimately declare themselves and be removed. Still it is necessary to realise the fact that it is not possible to exterminate the disease in any locality in even two years, no matter how effectively the work is done. There are many villages in the Godavari where effective cutting has been in progress for little more than a year and these must continue to return a considerable number of cases for some time to come.

The operations have been entirely successful in limiting the disease in the Godavari District to the area previously infected. Now that they have been extended into Kistna, it is fully trusted that they will be equally successful in checking the alarming spread to the South which has been going on for some time in that direction. This alone should fully justify the cost of the operations and their continuation.

It is unfortunately impossible to estimate the number of trees saved from attack within the infected area. If the proportionate number of new cases monthly shown in the preceding table is anything like a true indication, the number saved last year must be very large. In much of Amalapur and Ramachendrapur Taluks the table most probably represents the actual state of affairs, but it cannot be applied to villages where the operations were late in starting. Still the number of trees saved in those parts where the work has been longest in progress must be many thousands, and apart from preventing any extension in the Godavari District it is not unlikely that the value of the palms actually saved within the district, already exceeds the cost of the operations.

PUSA,
The 1st May 1910.

E. J. BUTLER.

DESCRIPTION OF THE PLATES.

PLATE I. Views in Godavari with healthy and diseased palmyra palms.

PLATE II. Palm climbers and their work.

PLATE III. Upper figure: a severely diseased clump of palms. Lower figures: spots on leaf-sheath and leaf-blade of palmyra.

PLATE IV. *Pythium palmivorum*, Bull. All figures magnified 320 diameters except when otherwise stated.

Fig. 1. Superficial branched hypha.

„ 2. Superficial mycelial web bearing sporangia.

„ 3. Sporangia on long stalks, from a young culture in a moist atmosphere.

„ 4. Small sporangia, formed laterally on old hyphæ when placed in a moist atmosphere. × 186.

„ 5. Irregularly shaped sporangia.

Figs. 6 & 7. "Pythium" type of germination of the sporangium.

Fig. 8. "Phytopthora" type of germination of the sporangium.

„ 9. Germination of the zoospores within the sporangium.

Figs. 10 & 11. Germination of the sporangia by germ-tubes. 10. *a*, *b* and *c*, single germ-tube from the apical papilla, with early formation of secondary sporangia in *b* and *c*. *d*, single germ-tube laterally from below the papilla. 11. Multiple germ-tubes.

Fig. 12. Germination of the zoospores.

„ 13. Degeneration of a zoospore without germination.

„ 14. Germination of two double zoospores.

„ 15. Penetration of the sporangial wall by germ-tubes of zoospores which have failed to escape from the sporangium. *a* and *b* profile and surface views showing the swollen vacuolate apex of the germ-tube and the swelling and gelatinization of the wall at the point in contact with the apex. *c* penetration effected. × about 400.

PLATE V. Figs. 1 to 10. Resting spores of *Pythium palmivorum*. × 640.

Fig. 1. Resting spores with septate stalk hyphæ.

Figs. 2, 3 & 4. Irregularly swollen and branched stalk hyphæ. In figs. 2 and 4 the branches simulate antheridia.

Fig. 5. A cluster of resting spores on branched swollen stalks.

„ 6. Resting spore on the tip of a long unseptate hypha.

„ 7. Intercalar resting spore.

Figs. 8 & 9. Irregularly shaped resting spores.

Fig. 10. Germination of the resting spores with early formation of secondary sporangia. At *a*, the stalk is inserted laterally.

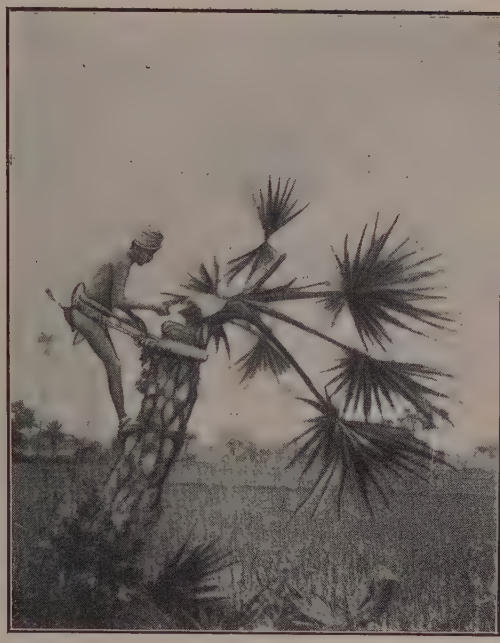
„ 11. Part of a section of the leaf-sheath of palmyra showing the hyphæ in the tissues and emerging from the stomata. Note at *a*, a hypha imbedded in the cuticle, but whether entering or emerging could not be determined. At *b*, three epidermal cells with hyphæ within them ; elsewhere the hyphæ occur only between the cells, into which they send haustoria. × 600.

Plate I.

Landscape in Godavari with Palmyras.

Palms attacked by Red Rot

A Palm climber.



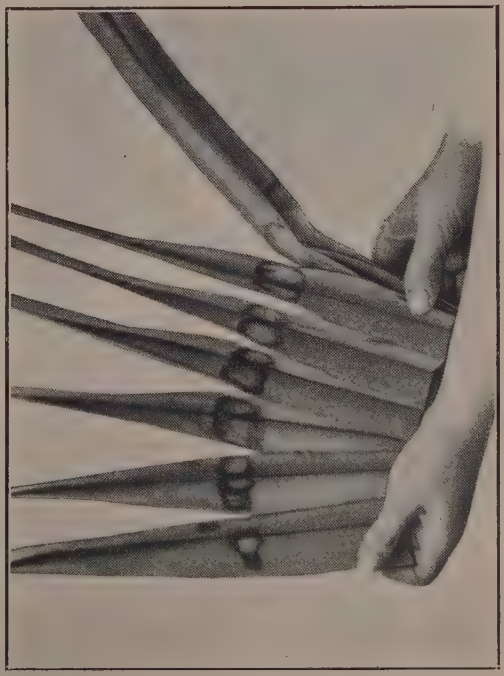
Palm climber at work.

Palm climber at work.

Plate III.

Palms attacked by Bud-Rot.

Spots on Leaf-sheath.

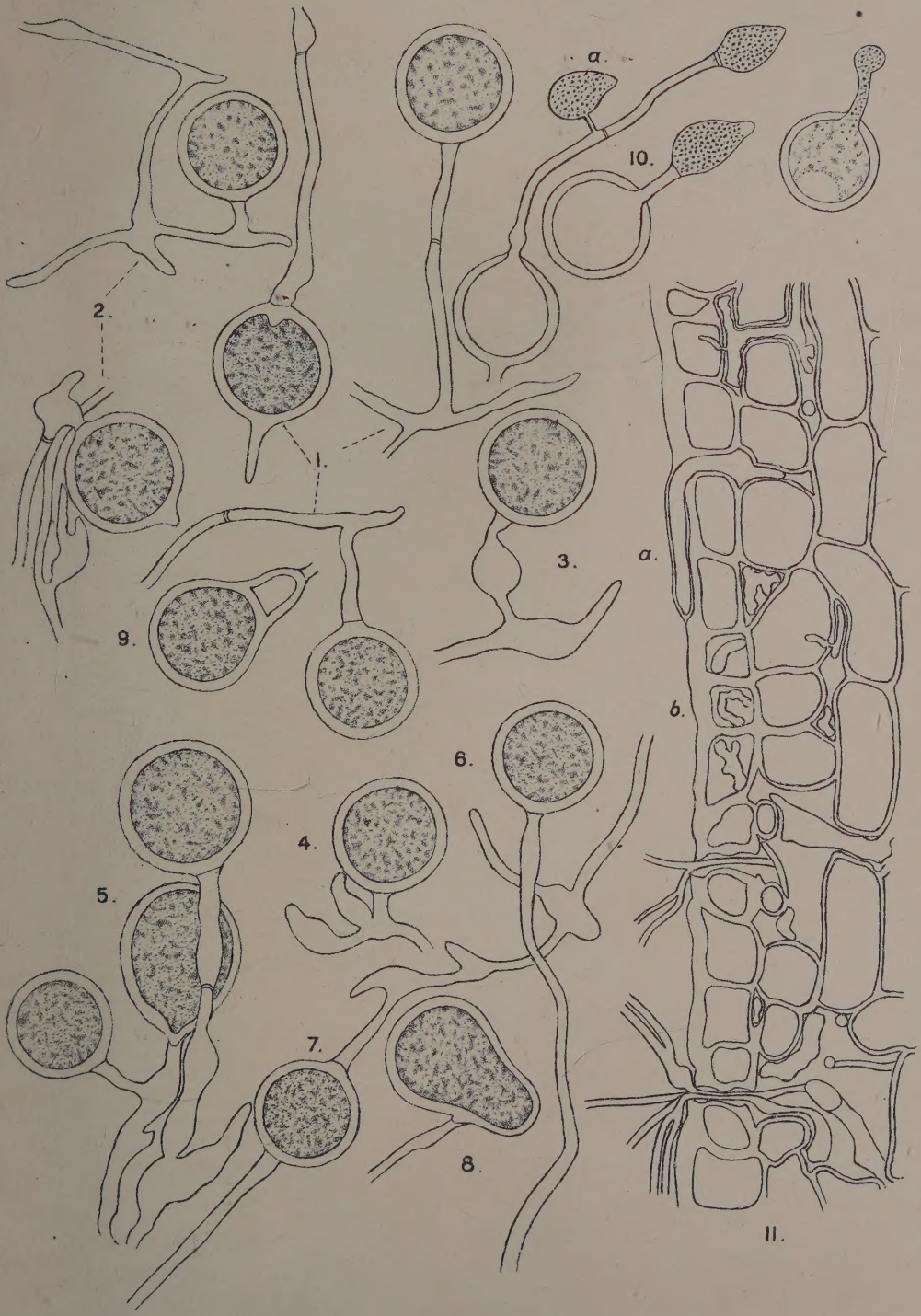


Spots on Leaf-blade.

PLATE IV.

PYTHIUM PALMIVORUM.

PLATE V.



PYTHIUM PALMIVORUM.